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THE EDITOR IS INDEBTED TO BARBARA SOKOLOFF, ELAINE SOKOLOFF AND SANG PARK FOR ASSISTANCE IN THE PREPARATION AND DISTRIBUTION OF TIB 37

ANNOUNCEMENT I

7th International Working Conference on Stored-product Protection

Beijing China, October 14-19,1998

Pre-Registration Form

(please type or print)

Given name:_____ Family name: _____

Title:(Mr\Mrs\Dr\Prof\etc):_____

Institute/company:_____

_____

Postal address:_____

_____

City/Town:_____ State/Region:_____ Country: _____

Fax:_____ Email:_____

(Please tick appropriate box below)

Contributed paper(s):

I intend to present a paper: for oral ☐ poster ☐

Title of paper:_____

_____

Specialist workshops: (The following workshops are intended to be organized.)

- I would like to attend:
  - Future of fumigation technology and its alternatives ☐
  - Application of computers in stored-products protection ☐
  - Minimum Standards for research topics ☐
  - Technology transfer and adoption ☐
- I would like to suggest the following topic(s) for specialist workshop(s):

_____

- I would be interested in organizing a specialist workshop on the following topic:

_____

Conference Tours: (see the second circular)

I am interested in Beijing Tours: BT-1 ☐ BT-2 ☐ BT-3 ☐

I am interested in Post-conference Tours: PT-1 ☐ PT-2 ☐

Name for name-tag:

Please print below exactly how you would like your name to be read:

7th International Working Conference on Stored-product Protection

Beijing China, October 14-19, 1998

Name:

Country:

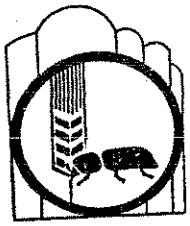
Name of Accompanying Person:

Closing date for returning the Pre-registration Form-------December,1997

(Quarantine and Quarantine Treatments — Feb.28,1998)

Please complete and send this form as soon as possible to 7th IWCSPP Secretariat:

95 Huapaifang Street, Chengdu, Sichuan 610031, People's Republic of China



7th International Working Conference on Stored-product Protection

Beijing China, October 14-19,1998

Abstract Form

(please type or print)

Please tick appropriate box oral ☐ poster ☐ **Abstract: max 200 words**

Title of paper: _____

_____

Author(s): _____

Address: _____

Abstract submitted no later than——March 31, 1998

Please complete and send this form as soon as possible to 7th IWCSPP Secretariat:

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ANNOUNCEMENT II

FOR SALE

A SMALL NUMBER OF SETS OF SOKOLOFF'S THREE VOLUME THE BIOLOGY OF TRIBOLIUM WITH SPECIAL EMPHASIS ON GENETIC ASPECTS IS AVAILABLE FROM THE EDITOR ON A FIRST COME-FIRST SERVED BASIS AND ONLY AS A FULL THREE VOLUME SET. PRICE: $100/SET, PLUS POSTAGE, HANDLING, AND INSURANCE.

ANNOUNCEMENT III

WITH THIS ISSUE (TIB 36) THE EDITOR INITIATES A NEW SECTION OF THE TIB: AN OPEN FORUM FOR DISCUSSION OF CURRENT PROBLEMS IN TRIBOLIUM OR IN POPULATION BIOLOGY IN GENERAL. THE FIRST TOPIC OF DISCUSSION IS ENTITLED "INTERACTIONS IN TRIBOLIUM: COMPETITION OR PREDATOR-PREY?", A TOPIC WHICH HAS BEEN IN THE EDITOR'S MIND FOR SOME TIME, BUT IT SOLIDIFIED RECENTLY AS A RESULT OF A REVIEW OF THE LITERATURE SINCE 1977 (WHEN VOLUME III OF THE BIOLOGY OF TRIBOLIUM WITH SPECIAL EMPHASIS ON GENETIC ASPECTS WAS PUBLISHED.

THE TITLE IS SELF-EXPLANATORY. I HOPE THAT COLLEAGUES AND/OR THEIR STUDENTS WILL RESPOND TO THE PAPER'S QUESTION FOR INCLUSION IN LATER ISSUES OF TIB. THE REPLY MAY BE SHORT OR LONG, TECHNICAL OR NON-TECHNICAL, AND MAY VOICE AN OPINION, EITHER PRO OR CONTRA THE QUESTION. IT MAY INCLUDE MATHEMATICAL EQUATIONS TO PROVE THAT COMPETITION AND PREDATOR-PREY ARE OR ARE NOT DIFFERENT INTERACTIONS, OR THEY MAY BE CONSIDERED THE SAME TYPE OF INTERACTION.

IF ENOUGH INFORMATION IS AVAILABLE, WE MAY SUBMIT THE CONTRIBUTIONS TO A JOURNAL FOR PUBLICATION, AND PERHAPS WE CAN ORGANIZE A SYMPOSIUM AT A FUTURE MEETING.

THE TRIBOLIUM INFORMATION BULLETIN CAN ONLY SURVIVE BY CONTRIBUTIONS OF COLLEAGUES' RESEARCH FOR ITS EXISTENCE. PLEASE BE AS GENEROUS OF YOUR TIME AS POSSIBLE BY RESPONDING WHEN CALLS FOR CONTRIBUTIONS ARRIVE IN YOUR HANDS.

A. SOKOLOFF

ANNOUNCEMENT IV

Tribolium News Exchange member list.

A small group of Tribolium investigators have initiated a Tribolium News Exchange. Its purpose is to provide an informal forum to exchange ideas, techniques and suggestions about Tribolium.

If you wish to join the Tribolium News Exchange Group, contact Margaret Bloch Qazi at her email address:
tribolium@emerald.tufts.edu

June 1996

Tribolium News Exchange - ELECTRONIC MAIL ADDRESSES.

The following includes an updated list of people subscribed to the Tribolium News Exchange. The purpose of this group is to provide an informal forum to exchange ideas, techniques and suggestions about Tribolium. To send electronic mail to the group, address it to: tribolium@emerald.tufts.edu

If you have suggestions of other people not included on this list who you think would be interested in participating, please send their addresses to me.

Happy beetling,

Margaret Bloch Qazi

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STOCK LISTS

BURLINGTON, NORTH CAROLINA
CAROLINA BIOLOGICAL SUPPLY COMPANY

Tribolium castaneum

1. black
2. jet
3. pearl
4. Wild
5. High body weight
6. Low body weight

Tribolium confusum

1. Wild

(Ed.).

BURLINGTON, VERMONT 05401
UNIVERSITY OF VERMONT
DEPARTMENT OF ZOOLOGY
STEVENS/GOODNIGHT LAB

T. confusum	T.castaneum	Oryzaephilus surinamensis
bI	cI	
bII	cSM-+/+	
bIII	cCM-b/b	
bIV	cIV-a	
b-Chicago b/b	c-Brazil	
b-Chicago	c-Costa Rica	
b-Circle	c-Thailand	
b-yugo-Illinois b/b	c-Spain	
b-yugo-Illinois +/+	c-Israel	
bSM		
b-yugo-Kentucky		
b-McGill		
b-Thailand		
b- Nigeria		
b-Pakistan		

L. Stevens

CARBONDALE, ILLINOIS 62901
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DEPARTMENT OF ZOOLOGY

Tribolium castaneum

I. Wild type strains

1. Purdue + Foundation

II. Mutant strains

1. antennapedia (ap)

D.C. Englert

Chicago, Illinois 60637-1573
The University of Chicago
Department of Ecology and Evolution

Stock lists
I. Wild type strains
A. Tribolium castaneum
1. c+, "Chicago" (from Thomas Park)
2. c-ARK, Arkansas
3. c-YUGO, Yugoslavia, now Croatia
4. c-Texas
5. c-BS, collected in Naperville, IL, on birdseed
6. c-Infantes, Spain
7. c-Jerez, Spain
8. c-Campanaro, Spain
9. c-Osaka, Japan
10. c-Nigeria

B. Tribolium confusum (*= infected with Wolbachia pipientis)

*1. b+, "Chicago" from Thomas park)
2. b-I, inbred strain derived from (1).
*3. b-II, inbred strain
*4. b-III, " "
*5. b-IV " "
*6. b-YUGO, Yugoslavia, now Croatia
7. b-YUGO, "
8. b-Illinois
9. b-Mississippi
10. b-Nigeria

Michael J. Wade Norman T. Johnson

CORAL GABLES, FLORIDA
UNIVERSITY OF MIAMI
DEPARTMENT OF BIOLOGY

I wild type strains

1. Tribolium confusum (Chicago)
2. T. castaneum (Chicago)

II Mutant

1. T. confusum - ebony (SOKOLOFF)
2. T. castaneum - jet (from Chicago wild)
3. T. castaneum - Chicago black (Sokoloff)
4. T. castaneum - dark soooty (Sokoloff)

Earl R. Rich

Present Tribolium wok limited to homosexual behavior in melanic mutants.

RIVER FOREST, ILLINOIS
ROSARY COLLEGE
DEPARTMENT OF NATURAL SCIENCES

I. Wild type strains
 A. Tribolium castaneum
  1. "Chicago" (originally from Thomas Park)
  2. "Brazil" (originally from Rio de Janeiro; also known as cI)
  3. "Arkansas" (originally from Michael Wade)
 B. Tribolium confusum
  1. "Chicago" (originally from Thomas Park)
  2. "Circle" (collected in Chicago)
  3. bI (derived from "Chicago")
  4. bII (derived from "Chicago")
  5. bIII (derived from "Chicago")
  6. bIV (derived from "Chicago")

II. Mutant strains
 A. Tribolium castaneum
  1. "Chicago" black (derived from "Chicago")
 B. Tribolium confusum
  1. "Chicago" black (derived from "Chicago")

David M. Craig

GAINESVILLE, FLORIDA
ARS, USDA
P.O. BOX 14565
INSECT ATTRACTANTS, BEHAVIOR AND BASIC BIOLOGY LABORATORY.

Attagenus megatoma	black carpet beetle
Cadra cautella	almond moth
Cylas formicarius elegantulus	sweet potato weevil
Lasioderma serricorne	cigarette beetle
Oryzaephilus surinamensis	sawtoothed grain beetle
Paramyelois transitella	navel orangeworm
Plodia interpunctella	Indian meal moth
Sitotroga cerealella	Angoumois grain moth
Sitophilus oryzae	rice weevil
Tribolium castaneum	red flour beetle
Trogoderma granarium	khapra beetle
Trogoderma inclusum	

(Ed.).

KINGSTON, RHODE ISLAND 02881
UNIVERSITY OF RHODE ISLAND
DEPARTMENT OF ZOOLOGY

Tribolium castaneum

Purdue Foundation	via Purdue
Black Foundation	via Purdue
Corn oil unsaturated fatty acid sensitive (cos)	

Tribolium confusum

Chicago	Park 1955
black	via San Bernardino
pearl	via San Bernardino

Tribolium madens via San Bernardino

Tribolium brevicornis via San Bernardino

(Ed.).

LAFAYETTE, INDIANA 47907
PURDUE UNIVERSITY
ANIMAL SCIENCES DEPARTMENT

Tribolium castaneum

I. Wild type strains

A. Foundation "+" - originated in 1954 at Purdue University from a broad genetic base and maintained with no artificial selection and minimal breeding.

B. Foundation s - Same genetic base as Foundation "+", but genetically marked with the sooty mutant (s).

C. Foundation b - Originated in 1959 at Purdue University with a broad genetic base unrelated to Foundation "+", no artificial selection, minimal inbreeding, and genetically marked with the black mutant (b).

D. Foundation p - Originated in 1959 at Purdue University with a broad genetic base unrelated to Foundation "+" and b, no selection, minimal inbreeding, and genetically marked with the pearl mutant (p).

W.M. MUIR

LEXINGTON, KENTUCKY
UNIVERSITY OF KENTUCKY
AGRICULTURAL EXPERIMENT STATION

I. Base populations

1. Purdue + foundation	Purdue
2. Purdue s foundation (sooty)	Purdue
3. Purdue b foundation (black)	Purdue
4. Purdue p foundation (pearl)	Purdue

II. Synthetic strains -- with a history of long-term selection for increased pupa weight but maintained in population cages without selection pressure but discrete generations.

1. MRS-1	Minnesota, 1970
2. MRS-2	Minnesota, 1970
3. P	Purdue, 1976

4. C Davis, 1976

III. Synthetic strain IS from a cross of CSI-10 X E1 inbred lines,maintained in population cages with extremely large
1. IS - From a cross of CSI-10 X e1 inbred lines, maintained in population cages with extremely large population size and random mating for 28 generations.

(Ed.).

MANHATTAN, KANSAS
KANSAS STATE UNIVERSITY
DEPARTMENT OF ENTOMOLOGY

LEPIDOPTERA

Phycitidae: Cadra cautella and Plodia interpunctella

Gelechiidae: wild and red eyed strains.

Pyralidae: Corcyra cephalonica

COLEOPTERA

Anobiidae: Lasioderma serricorne and Stegobium paniceum

Bostrichidae: Rhyzopertha dominica

Bruchidae: Callosobruchus maculatus

Cucujidae; Cryptolestes ferrugineus, C. pusillus,

Curculionidae: Sitophilus granarius, S. oryzae, and two strains of S. zeamais.

Dermestidae: Trogoderma inclusum, Attagenus megatoma

Ostomatidae: Tenebroides mauritanicus

Ptinidae: Gibbium psylloides

Silvanidae; Ahasverus advena, Oryzaephilus surinamensis, O. mercator

Tenebrionidae:

Palorus ratzeburgi,Kansas 1965
Tenebrio molitor, Kansas
Tenebrio obscurus Manhattan, Kansas, 1971
Tribolium castaneum, Kansas
Tribolium confusum, Kansas

Valerie Wright

MANHATTAN, KANSAS 66502
U.S. GRAIN MARKETING RESEARCH LABORATORY

Tribolium castaneum

I. Insecticide-resitant strains

1. GA-1, malathion-specific, collected in Georgia, 1980
2. NC-1, malathion-specific, collected in North Carolina. From W.C. CAMPBELL.
3. Kano, malathion-specific, collected in northern Nigeria, 1961. From W.R. wilkin.
4. CTC 12, nonspecific, oxidase type, collected in Kingaroy, Australia, 1968. From W.R. Wilkin.
5. TC 95, nonspecific. From B.R. Champ.
6. DDT C, DDT-resistant, collected in South Africa, 1959. From D.G. Blackman.
7. Rmal-2 allelic to Rmal-1
8. Rdiel--Resistant to lindane, dieldrin and other cyclodienes, linkage group not determined.

II. Mutant strains

(see next pages)

Mutant	Full Name or description	Link. Group	Stocks	Source
1S65	Crossover supressor	2;9	1S65/mas,p	Manhattan
3P1	crossover supressor	3	3P1/au14	Purdue
3P2	crossover supressor	3	3P2/au14, 3P2/X(ab-2s)	Purdue
A(Ag1),Stm	abdominal (fr. Ag), cis Stm	2	A(Ag1), Stm /ptlD60	Manhattan
A(Ag2)	abdominal (from Ag)	2	A(Ag2)/Ey	Manhattan
A(mc)	abdominal (from mc)	2	A(mc),p/Stm,Cx5	Manhattan
A10	Abdominal 10	2	A10 / Ey	Manhattan
A10	Abdominal 10	2	A10,mxpA10/Utx1,mxp,apt	Manhattan
A10,mxpA10	Abdominal 10, mxp fr. A10	2	A10,mxpA10/Utx1,mxp,apt	Manhattan
A12	Abdominal 12	2	A12/Ey	Manhattan
A15, Stm	Abdominal 15, Stm cis	2	A15,Stm/Ey	Manhattan
A20 Rdiel	Dieldrin resistant	2	A20 Rdiel	Unknown
A4	Abdominal 4	2	A4/Stm,Cx5	Manhattan
A8	Abdominal 8	2	A8/Stm,Cx5	Manhattan
ab	antenna bifurcada	9	ab,pas30,p	Bogota, Colombia
ab	antenna bifurcada	9	ub,ab	Bogota, Colombia
ab	antenna bifurcada	9	ab/ab	Bogota, Colombia
ab	antenna bifurcada	9	ue,ab,msg,p,mxp,apt,pas30	Bogota, Colombia
AD100,Stm,Cx5	Notched gena,Stm,Cx5 (cis)	2	AD100,Stm,Cx5/Es1	Manhattan
Ag	Antennagalea	2	Ag/Es1	Manhattan
Ag	Antennagalea	2	Ag/mxpNG	Manhattan
Ag+RptlD1	Ag revertant-dominant ptl	2	Ag+RptlD1/Es1	Manhattan
Ag2, Stm	Antennagalea 2, Stm (cis)	2	Ag2,Stm/Ey	Manhattan
Ag5, Stm	Antennagalea 5, Stm (cis)	2	Ag5,Stm/Es1	Manhattan
AgPin	Antennagalea (Pinhead)	2	AgPin/Stm,Cx5	Manhattan
Ah	Arrowhead	8	Ah	Purdue
ap	antennapedia	8	b, ap	San Bernadino
ap	antennapedia	8	Bald,ap,sq1/ap,sq1	San Bernadino
ap	antennapedia	8	Bald,ap,sq2/ap,sq2	San Bernadino
ap	antennapedia	8	MMS (s.c,ap,au,mas)	San Bernadino
ap(psl)	ap(pleurosternal sutures incompl.	8	ap(psl)	Manhattan
Apl	Antennapalpus	2	Apl, apt, ub	Manhattan
Apl	Antennapalpus	2	Apl,apt,mas,pas	Manhattan
Apl	Antennapalpus	2	Apl/Apl	Manhattan
apt	alate prothorax	2	apt, mas, p	Manhattan
apt	alate prothorax	2	apt, pas	San Bernadino
apt	alate prothorax	2	b, apt, sa, c	San Bernadino
apt	alate prothorax	2	ba,mxp,apt,pas30	San Bernadino
apt	alate prothorax	2	Quad(mxp,apt,mas,pas	San Bernadino
apt	alate prothorax	2	quint	San Bernadino
apt	alate prothorax	2	s,h,b(t),mxp,apt,pas30	San Bernadino
apt	alate prothorax	2	s,h,j2,mxp,apt,pas30	San Bernadino
apt	alate prothorax	2	Utx1,mxp,apt/mxpX9,Es1	San Bernadino
apt	alate prothorax	2	s,j,b(t),mxp,apt,pas30,h	San Bernadino
au	aureate	3	au	San Bernadino
au	aureate	3	b(t),p,lod,au,msg	San Bernadino
au	aureate	3	au,lod isoline (JS)	San Bernadino
au	aureate	3	mas, p,au	San Bernadino
au	aureate	3	MMS (s.c,ap,au,mas)	San Bernadino
au14	aureate 14, lethal	3	3P1/au14, 3P2/au14	Purdue
b	black body color	3	b	San Bernadino
b	black body color	3	b, ap	San Bernadino
b	black body color	3	b, apt, sa, c	San Bernadino
b(ST)	black, dominant	3	Chr/b(ST)	Manhattan
b(t)	tawny body color	3	b(t)	San Bernadino
b(t)	tawny body color	3	b(t),p,lod,au,msg	San Bernadino
b(t)	tawny body color	3	s,h,b(t),mxp,apt,pas30	San Bernadino
b(t)	tawny body color	3	s,j,b(t),mxp,apt,pas30,h	San Bernadino
ba	broken antennae	2	ba, pas30	Manhattan
ba	broken antennae	2	ba, pas30	Manhattan
Bald	Bald (reduced setiferous pits)	8	Bald	Manhattan
Bald	Bald (reduced setiferous pits)	8	Bald,ap,sq1/ap,sq1	Manhattan

Bald	Bald (reduced setiferous pits)	8	Bald,ap,sq2/ap,sq2	Manhattan
Bamp14	Blunt anterior metastern. projection	3	Bamp14	Manhattan
Bamp27	Blunt anterior metastern. projection	3	Bamp27	Manhattan
Bamp27,au	Blunt anterior metastern. projection	3	Bamp27,au/au	Manhattan
Bamp29	Blunt anterior metastern. projection	3	Bamp29	Manhattan
Bamp31	Blunt anterior metastern. projection	3	Bamp31/+	Manhattan
Bamp31	Blunt anterior metastern. projection	3	Bamp31/Chr	Manhattan
Bamp58	Blunt anterior metastern. projection	3	Bamp58	Manhattan
BampSp	Blunt anterior metastern. projection	3	BampSp	Manhattan
Be	Bar eye	4	Be	San Bernadino
Be	Bar eye	4	Be, s	San Bernadino
box	box (abdominal)	2	box / Es	Manhattan
c	chestnut eye	7	b, apt, sa, c	San Bernadino
c	chestnut eye	7	sa,c	San Bernadino
c	chestnut eye	7	MMS (s.c,ap,au,mas)	San Bernadino
Cg	Cleft gular (sutures)	?	Cg	Manhattan
Chr	Charcoal body color	3	Bamp31/Chr	San Bernadino
Chr	Charcoal body color	3	Chr	San Bernadino
Chr	Charcoal body color	3	Chr/b(ST)	San Bernadino
ChrE	Charcoal (Elytra indented)	3	ChrE	Manhattan
co	cola body color	9	co,p	Manhattan
co	cola body color	9	Se,co	Manhattan
co	cola body color	9	Se,co,p	Manhattan
Crab	Crab (warped legs)	7	Crab	Manhattan
Crab	Crab (warped legs)	7	Crab,s	Manhattan
Crab	Crab (warped legs)	7	Crab/PL4	Manhattan
CTC 12 Rabon R	Rabon resistant	?	CTC 12 Rabon R	Australia
Cv	Cross-veined elytra	?	Cv	Purdue
Cx20	Cephalothorax 20	2	Cx20/Es1	Manhattan
Cx6	Cephalothorax 6	2	Cx6/Es1	Manhattan
Dch1	Dachshund 1	2;9	Dch1/Es1	San Bernadino
Dch13,Stm	Dachshund 13, Stm (cis)	2	Dch13,Stm/Es1	Manhattan
Dch4	Dachshund 4	2	Dch4 / Es	Manhattan
Det43	Divergent elytral tips	4;5	Det43,h,s/Es,h,s	Manhattan
Det43	Divergent elytral tips	4;5	Det43/Es1	Manhattan
Df(Dch1)	Deficiency (from Dch1)	2	Df(Dch1)/Ey	Manhattan
Df(Lu)/Df(Lu)	Deficiency (from Lu)	2?	Df(Lu)/Df(Lu)	Manhattan
Df1-3/Ey	Deficiency	2	Df1-3/Ey	Manhattan
Df1-5/Ey	Deficiency	2	Df1-5/Ey	Manhattan
Dp	Duplication (from Dch1)	2	Dp/Es1/A10	Manhattan
Dp	Duplication (from Dch1)	2	Dp/Es1/Df(Dch)	Manhattan
Dp	Duplication (from Dch1)	2	Dp/Es1/Df1-3	Manhattan
Dp	Duplication (from Dch1)	2	Dp/Es1/pas30	Manhattan
Dp	Duplication (from Dch1)	2	Dp/Ey/Ey	Manhattan
Dp	Duplication (from Dch1)	2	Dp/Stm,ptID57/pas30	Manhattan
DpLu	Duplication (from Lu)	2	DpLu/Ey	Manhattan
DpSpa	Duplication (from Spa)	2	DpSpa/Es1/pas30	Manhattan
Ds	Displaced sternellum	4	Ds/Spa (no Medea)	Manhattan
ds(euD)	displaced sternellum (from euD)	?	ds(euD)	Manhattan
ds-X	displaced sternellum, x-linked	4?;X	ds-X	Manhattan
dve(mas,pas)	divergent elytra (from mas,pas stock	?	dve(mas,pas)	Manhattan
Em,A16s	Enlarged mentum, abdominal (cis)	2	Em,A16s/Stb	Manhattan
Er	Eye reduced	2	Er	Manhattan
Er	Eye reduced	2	Er,quint	Manhattan
Er	Eye reduced	2	Er,ub	Manhattan
Es	Extra sclerite (abdominal)	2;4	AD100,Stm,Cx5/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Ag+RptID1/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Ag/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Ag5,Stm/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	box / Es	Manhattan
Es	Extra sclerite (abdominal)	2;4	Cx20/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Cx6/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Dch1/Es1	Manhattan

Es	Extra sclerite (abdominal)	2;4	Dch13,Stm/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Det43/Es	Manhattan
Es	Extra sclerite (abdominal)	2;4	Dp/Es1/A10	Manhattan
Es	Extra sclerite (abdominal)	2;4	Dp/Es1/Df(Dch)	Manhattan
Es	Extra sclerite (abdominal)	2;4	Dp/Es1/Df1-3	Manhattan
Es	Extra sclerite (abdominal)	2;4	Dp/Es1/pas30	Manhattan
Es	Extra sclerite (abdominal)	2;4	DpSpa/Es1/pas30	Manhattan
Es	Extra sclerite (abdominal)	2;4	Es/tr	Manhattan
Es	Extra sclerite (abdominal)	2;4	Ey/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	g/Es	Manhattan
Es	Extra sclerite (abdominal)	2;4	Ip69/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Spa/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Stb,Df(mas)/Es	Manhattan
Es	Extra sclerite (abdominal)	2;4	Stb/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Stbd/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Stm+RSptID/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Stm,Ag4/Es	Manhattan
Es	Extra sclerite (abdominal)	2;4	Stm,Cx5/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Stm,Ns/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Stm-Es1/+NDJ	Manhattan
Es	Extra sclerite (abdominal)	2;4	Stm-Skl4-Es/+ NDJ	Manhattan
Es	Extra sclerite (abdominal)	2;4	StmR1/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	StmR2/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	StmR5/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	StmR6/Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Utx1,mxp,apt/mxpX9,Es1	Manhattan
Es	Extra sclerite (abdominal)	2;4	Utx1/Es	Manhattan
Es	Extra sclerite (abdominal)	2;4	vwe/Es	Manhattan
Es(Skl6)	Extra sclerite (from Skl6)	2	Es(Skl6)	Manhattan
Es1+R1/Stm	Extra sclerite revertant 1	2	Es1+R1/Stm	Manhattan
Es1+R9/Ey	Extra sclerite revertant 9	2	Es1+R9/Ey	Manhattan
Es2/Ey	Extra sclerite 2	2	Es2/Ey	Manhattan
Es3/Ey	Extra sclerite 3	2	Es3/Ey	Manhattan
eu	extra urogomphi	2	eu	San Bernadino
eu	extra urogomphi	2	eu, apt, mas	San Bernadino
eu	extra urogomphi	2	eu, mas	San Bernadino
eu	extra urogomphi	2	eu, mas, pas	San Bernadino
euD	Extra urogomphi (Abd B)	2	euD	Manhattan
Ey	eyeless	2;5	A(Ag2)/Ey	Manhattan
Ey	eyeless	2;5	A10 / Ey	Manhattan
Ey	eyeless	2;5	A12/Ey	Manhattan
Ey	eyeless	2;5	A15,Stm/Ey	Manhattan
Ey	eyeless	2;5	Ag2,Stm/Ey	Manhattan
Ey	eyeless	2;5	Dch3 / Ey	Manhattan
Ey	eyeless	2;5	Df(Dch1)/Ey	Manhattan
Ey	eyeless	2;5	Df(Lu)/Df(Lu)	Manhattan
Ey	eyeless	2;5	Df1-3/Ey	Manhattan
Ey	eyeless	2;5	DpLu/Ey	Manhattan
Ey	eyeless	2;5	Ey/Es1	Manhattan
Ey	eyeless	2;5	Lu,Skl6/Ey	Manhattan
Ey	eyeless	2;5	ptID16,Stm/Ey	Manhattan
Ey	eyeless	2;5	Mcs1R1/Ey	Manhattan
Ey	eyeless	2;5	Mcs1R2/Ey	Manhattan
Ey	eyeless	2;5	Mcs1R5/Ey	Manhattan
Ey	eyeless	2;5	mxpD1,Skl6/Ey	Manhattan
Ey	eyeless	2;5	mxpX9,Es1/Ey	Manhattan
Ey	eyeless	2;5	Df1-5/Ey	Manhattan
Ey	eyeless	2;5	ptID57,Stm/Ey	Manhattan
Ey	eyeless	2;5	ptID60/Ey	Manhattan
Ey	eyeless	2;5	Skl4/Ey	Manhattan
Ey	eyeless	2;5	Skl4R1/Ey	Manhattan

Ey	eyeless	2;5	Skl4R2/Ey	Manhattan
Ey	eyeless	2;5	Stm,Cx5/Ey,A14	Manhattan
Ey	eyeless	2;5	Stm,Cx5/Ey; s/s	Manhattan
Ey,A14	Eyeless, Abdominal 14 (cis)	2	Stm,Cx5/Ey,A14	Manhattan
Ey-Lethal-Free	lethal free from Eyless	NA	Ey-Lethal-Free	Manhattan
fs(sa)	short antennae, female sterile	?	fs(sa)	Manhattan
Fta	Fused tarsi and antennae	?	Fta	San Bernadino
g	glossy	2	g	Manhattan
g	glossy	2	g/Dch3	Manhattan
g	glossy	2	g/Es	Manhattan
Ga-1	Georgia 1, wild type	NA	Ga-1	Georgia
Ga-1	Georgia 1, wild type	NA	Ga-9s	Georgia
Gl	Giant (body size)	NA	Gl	San Bernadino
Go	Goliath (body size)	7	Go	Manhattan
h	hazel eye	4	Det43/Es	San Bernadino
h	hazel eye	4	h, s	San Bernadino
h	hazel eye	4	s,h,b(t),mxp,apt,pas30	San Bernadino
h	hazel eye	4	s,h,j2,mxp,apt,pas30	San Bernadino
Hw	Hairy wing	2	Hw/Es,mxpX9	Manhattan
Hw	Hairy wing	2	Hw/Stm,Cx5	Manhattan
Is	Incomplete sternellum	?	Is	Manhattan
j1	jet, body color	5	j,mc	San Bernadino
j1	jet, body color	5	rb,j	San Bernadino
j1	jet, body color	5	s,j,b(t),mxp,apt,pas30,h	San Bernadino
j2	jet, body color	5	j2	Cedar Rapids
j2	jet, body color	5	s,h,j2,mxp,apt,pas30	Cedar Rapids
ju	juvenile urogomphi	4?	ju,ptl	Manhattan
Lab-S Rusty	Lab strain, rusty, wild-type	NA	Lab-S Rusty	Manhattan
LF-3 (JS)	Lethal free	3	LF-3 (JS)	Purdue
lod	light optical diaphragm	3	au,lod isoline (JS)	San Bernadino
lod	light optical diaphragm	3	b(t),p,lod,au,msg	San Bernadino
lp69	labiopedia 69	2	lp69/Es1	Manhattan
lp69	labiopedia 69	2	lp69/Utx1,mxp,apt	Manhattan
Lu	Lucifer (dorsal head horns)	2	Lu / Stm,Cx5	Manhattan
Lu	Lucifer (dorsal head horns)	2	Lu,Skl6/Ey	Manhattan
Lu	Lucifer (dorsal head horns)	2	Lu,Skl6/Stb	Manhattan
Lu	Lucifer (dorsal head horns)	2	Lu/Stbd	Manhattan
m.l. 9.14	(Male linked)	2	9.14 (male linked)	Manhattan
M1	Medea 1	3	M1 - iso 3B1 (G)	Manhattan
M1	Medea 1	3	M1 isoline (JS)	Manhattan
M1	Medea 1	3	M1,au,M3	Manhattan
M1	Medea 1	3	M1,au,p,lod	Manhattan
M1	Medea 1	3	M1,b	Manhattan
M1	Medea 1	3	M1/M1, Bamp27	Manhattan
M3	Medea 3	3	M3,au	Manhattan
M3	Medea 3	3	M1,au,M3	Manhattan
mas	missing abdominal sternite	2	1S65/mas,p	San Bernadino
mas	missing abdominal sternite	2	apt, mas, p	San Bernadino
mas	missing abdominal sternite	2	mas	San Bernadino
mas	missing abdominal sternite	2	mas, p,au	San Bernadino
mas	missing abdominal sternite	2	mas, pas	San Bernadino
mas	missing abdominal sternite	2	ptl, mas, pas	San Bernadino
mas	missing abdominal sternite	2	Quad(mxp,apt,mas,pas	San Bernadino
mas	missing abdominal sternite	2	quint	San Bernadino
mas	missing abdominal sternite	2	MMS (s,c,mas,ap,au)	San Bernadino
mas2	missing abdominal sternite 2	2 ?	mas2	Manhattan
mc	microcephalic	5	j,mc	San Bernadino
mc	microcephalic	5	mc,rb,j	San Bernadino
mc	microcephalic	5	mc,j	San Bernadino
mc(eg)	microcephalic (eye growth)	5	mc(eg),p,lod	San Bernadino
Mc-2,Utx1	Microcephalic-2,Ultrathorax(cis)	2	Mc-2,Utx1/mxpNG	Manhattan
Mcs1	Miscadestral sclerite	2	Mcs1/Stm	Manhattan
Mcs1R1	Miscadestral sclerite, revertant 1	2	Mcs1R1/Ey	Manhattan

Mcs1R2	Miscadestral sclerite, revertant 2	2	Mcs1R2/Ey	Manhattan
Mcs1R4	Miscadestral sclerite, revertant 4	2	Mcs1R4/mxpNG	Manhattan
Mcs1R5	Miscadestral sclerite, revertant 5	2	Mcs1R5/Ey	Manhattan
Mo	Micro opthalmic	6	Mo	San Bernadino
msg	melanotic stink gland	?	b(t),p,lod,au,msg	San Bernadino
msg	melanotic stink gland	?	msg, pas	San Bernadino
msg	melanotic stink gland	?	ue,ab,msg,p,mxp,apt,pas30	San Bernadino
mt	melanotic tumors	?	mt	San Bernadino
mxp	maxillopedia	2	ba,mxp,apt,pas30	San Bernadino
mxp	maxillopedia	2	mxp, apt	San Bernadino
mxp	maxillopedia	2	mxp, apt, pas30	San Bernadino
mxp	maxillopedia	2	mxp, mas	San Bernadino
mxp	maxillopedia	2	ptl, mxp	San Bernadino
mxp	maxillopedia	2	A10,mxpA10/Utx1,mxp,apt	San Bernadino
mxp	maxillopedia	2	Quad(mxp,apt,mas,pas	San Bernadino
mxp	maxillopedia	2	quint	San Bernadino
mxp	maxillopedia	2	s,h,b(t),mxp,apt,pas30	San Bernadino
mxp	maxillopedia	2	s,h,j2,mxp,apt,pas30	San Bernadino
mxp	maxillopedia	2	s,j,b(t),mxp,apt,pas30,h	San Bernadino
mxp	maxillopedia	2	Utx1,mxp,apt/mxpX9,Es1	San Bernadino
mxp(Dch3)	maxillopedia dauchshund 3	2	X-31 pearl s.l./Dch3	Manhattan
mxp(Dch3)	maxillopedia dauchshund 3	2	X-31/Dch3	Manhattan
mxp(Dch3)	maxillopedia dauchshund 3	2	Dch3 / Ey	Manhattan
mxp(Dch3)	maxillopedia dauchshund 3	2	Dch3/X(ab-1s)	Manhattan
mxp(Dch3)	maxillopedia dauchshund 3	2	g/Dch3	Manhattan
mxp(Df1-3)	maxillopedia (from deficiency)	2	mxp(Df1-3)/Es	Manhattan
mxp170	maxillopedia 170, lethal	2	mxp170/Es1	Manhattan
mxp19	maxillopedia 19, lethal	2	mxp19/Es1	Manhattan
mxp8	maxillopedia 8, lethal	2	mxp8/Es1	Manhattan
mxpD1,Skl6/Ey	Maxillopedia, dom. 1, Skl6 (cis)	2	mxpD1,Skl6/Ey	Manhattan
mxpNG	maxillopedia, Notched Gena, lethal	2	mxpNG/Es1	Manhattan
mxpNG	maxillopedia, Notched gena	2	Ag/mxpNG	Manhattan
mxpNG	maxillopedia, Notched gena	2	Mc-2,Utx1/mxpNG	Manhattan
mxpNG	maxillopedia, Notched gena	2	Mcs1R4/mxpNG	Manhattan
mxpX9, Es	lethal maxillopedia, Es (cis)	2;4	Utx1,mxp,apt/mxpX9,Es1	Manhattan
mxpX9, Es	lethal maxillopedia, Es (cis)	2;4	mxpX9,Es1/Ey	Manhattan
mxpX9, Es	lethal maxillopedia, Es (cis)	2;4	Hw/Es,mxpX9	Manhattan
mxpX9,Es1/Ey	maxillopedia X9, lethal, Es (cis)	2;4	mxpX9,Es1/Ey	Manhattan
NDG-2 (#59)	Wild-type	NA	NDG-2 (#59)	Manitoba
p	pearl eye	9	1S65/mas,p	San Bernadino
p	pearl eye	9	ab,pas30,p	San Bernadino
p	pearl eye	9	apt, mas, p	San Bernadino
p	pearl eye	9	mas, p,au	San Bernadino
p	pearl eye	9	Se,co,p	San Bernadino
p	pearl eye	9	Se,p	San Bernadino
pas	pointed abdominal sternite	2	apt, pas	San Bernadino
pas	pointed abdominal sternite	2	ptl, mas, pas	San Bernadino
pas	pointed abdominal sternite	2	mas, pas	San Bernadino
pas	pointed abdominal sternite	2	Quad(mxp,apt,mas,pas	San Bernadino
pas	pointed abdominal sternite	2	quint	San Bernadino
pas30	pointed abdominal sternite 30	2	ab,pas30,p	Manhattan
pas30	pointed abdominal sternite 30	2	ba,mxp,apt,pas30	Manhattan
pas30	pointed abdominal sternite 30	2	s,h,b(t),mxp,apt,pas30	Manhattan
pas30	pointed abdominal sternite 30	2	s,h,j2,mxp,apt,pas30	Manhattan
pas30	pointed abdominal sternite 30	2	s,j,b(t),mxp,apt,pas30,h	Manhattan
pas30	pointed abdominal sternite 30	2	ub,pas30	Manhattan
pas30	pointed abdominal sternite 30	2	ue,ab,msg,p,mxp,apt,pas30	Manhattan
pd	paddle antenna	X	py, pd, plt	San Bernadino
PL4	Pseudo Linker 4	7;2	Crab/PL4	Manhattan
plt	platinum eye	X	py, pd, plt	San Bernadino
pnk (NDG-2)	pink eye, from NDG-2	?	pnk (NDG-2)	Manhattan
Ps	Pinched stemellum	2	Ps	San Bernadino
ptl	prothoraxless	2	ju,ptl	San Bernadino

ptl	prothoraxless	2	ptl	San Bernadino
ptl	prothoraxless	2	ptl, mas, pas	San Bernadino
ptl	prothoraxless	2	ptl, mxp	San Bernadino
ptlD16,Stm	Dom. prothoraxless 16, Stm (cis)	2	ptlD16,Stm/Ey	Manhattan
ptlD2	Dom. prothoraxless 2	2	ptlD2/Stb	Manhattan
ptlD26Y	Dom. prothoraxless 26, Y-linked	2;Y	ptlD26Y	Manhattan
ptlD57,Stm	Dom. prothoraxless 57, Stm (cis)	2	ptlD57,Stm/Ey	Manhattan
ptlD60	dominant prothoraxless 60	2	A(Ag1), Stm /ptlD60	Manhattan
ptlD60	dominant prothoraxless 60	2	ptlD60/Ey	Manhattan
py	pygmy	X	py, pd, plt	San Bernadino
py	pygmy	X	py, ser	San Bernadino
Pyr-R	Pyrethroid resistant	9	co,Pyr-R	Peter Collins
QTC 279 (Pyr-R)	Pyrethroid resistant	9?	QTC 279 (Pyr-R)	Peter Collins
Rap	Recurved anterior pronotum	2	Rap	Manhattan
rb	ruby eye	5	mc,rb,j	San Bernadino
rb	ruby eye	5	rb,j	San Bernadino
Rd	Reindeer, homozygous viable	2	Rd/Rd	Dawson
Rd	Reindeer, homozygous viable	2	Rd, mas, p	Dawson
Rd	Reindeer, homozygous viable	2	Rd,mc,p	Dawson
Rd	Reindeer, homozygous viable	2	Rd,pas30	Dawson
Rd(CS)	Reindeer, crossover suppressor	2	Ps/Rd(CS)	Manhattan
Rdlel BC9 Lab-S	Dieldrin resistant from Lab-S	NA	Rdlel BC9 Lab-S	Unknown
Rmal-2 (Cogburn)	Malation resistant	NA	Rmal-2 (Cogburn)	Texas
Russell 1 BC4s	spontaneous sooty ?	NA	Russell 1 BC4s	Russell, KS
Russell 2 BC4s	spontaneous sooty ?	NA	Russell 2 BC4s	Russell, KS
s	sooty	4	Crab,s	San Bernadino
s	sooty	4	s	San Bernadino
s	sooty	4	Det43,h,s/Es,h,s	San Bernadino
s	sooty	4	h, s	San Bernadino
s	sooty	4	s,h,b(t),mxp,apt,pas30	San Bernadino
s	sooty	4	s,h,J2,mxp,apt,pas30	San Bernadino
s	sooty	4	s,j,b(t),mxp,apt,pas30,h	San Bernadino
s	sooty	4	Be, s	San Bernadino
s	sooty	4	Ga-9s	San Bernadino
s	sooty	4	MMS (s.c.ap,au,mas)	San Bernadino
sa	short antenna	?	b, apt, sa, c	San Bernadino
sa	short antenna	?	sa,c	San Bernadino
Sa-8	Short antenna-8	?	Sa-8	Manhattan
sa-X	short antenna, X-linked	X	sa-X	Manhattan
Se	Short elytra	9	Se	Manhattan
Se	Short elytra	9	Se,co,p	Manhattan
Se	Short elytra	9	Se,p	Manhattan
se 46	short elytra 46	?	se 46	Purdue
Se-2	Short elytra 2	8	Se-2	Manhattan
Se12	Short elytra 12	?	Se12	Purdue
ser	serrate antenna	X	py, ser	San Bernadino
Skl2s	Socketless spontaneous 2	2	Skl2s/Stm,Cx5	Manhattan
Skl4/Ey	Socketless 4	2	Skl4/Ey	Manhattan
Skl4R1	Socketless 4, revertant 1	2	Skl4R1/Ey	Manhattan
Skl4R2	Socketless 4, revertant 2	2	Skl4R2/Ey	Manhattan
Skl4R3	Socketless 4, revertant 3	2	Skl4R3/Stm,Cx5	Manhattan
Skl6	Socketless 6	2	Skl6/Stm,Cx5	Manhattan
Skl6R1	Socketless 6, revertant 1	2	Skl6R1/Stm,Cx5	Manhattan
small	small body size	?	small	Purdue
sp	shoulder pads	2	sp/Dch3	Manhattan
sp	shoulder pads	2	sp/Stm,Ag4	Manhattan
Spa	Spatulate antennae	2;4	Ds/Spa (no Medea)	San Bernadino
Spa	Spatulate antennae	2;4	Spa/Es1	San Bernadino
sq (Tlw-2)	squint (from Tlw-1)	?	sq (Tlw-2)	India
sq-B	squint (from Burma)	?	sq-B	Burma
sq1	squint eye 1	8	Bald,ap;sq1/ap,sq1	San Bernadino
sq1	squint eye 1	8	sq1	San Bernadino

sq2	squint eye 2	8	ap,sq2	Manhattan
sq2	squint eye 2	8	Bald,ap,sq2/ap,sq2	Manhattan
Stb	Stubby antennae	2;X	Em,A16s/Stb	Manhattan
Stb	Stubby antennae	2;X	Lu,Skl6/Stb	Manhattan
Stb	Stubby antennae	2;X	Stb/Es	Manhattan
Stb,Df(mas)	Stubby, deficiency in mas	2	Stb,Df(mas)/Es	Manhattan
Stbd	Stuboid (short antennae)	2	Lu/Stbd	Manhattan
Stbd	Stuboid (short antennae)	2	Stbd/Es	Manhattan
Stm	Stumpy	2	Stm/Stm	Manhattan
Stm+RSptlD	Stm spontan. revert. ptl	2	Stm+RSptlD/Es1	Manhattan
Stm,Ag4	Stm, Antennagalea 4	2	X-83/Stm,Ag4	Manhattan
Stm,Ag4	Stm, Antennagalea 4	2	X-47/Stm,Ag4	Manhattan
Stm,Ag4	Stm, Antennagalea 4	2	vwe/Stm,Ag4	Manhattan
Stm,Ag4	Stm, Antennagalea 4	2	sp/Stm,Ag4	Manhattan
Stm,Ag4	Stm, Antennagalea 4	2	g/Stm,Ag4	Manhattan
Stm,Ag4	Stm, Antennagalea 4	2	X-31/Stm,Ag4	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	A4/Stm,Cx5	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	A8/Stm,Cx5	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	AgPin/Stm,Cx5	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	Lu / Stm,Cx5	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	Skl2s/Stm,Cx5	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	AD100,Stm,Cx5/Es1	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	AD100,Stm,Cx5/Es1	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	Skl2s/Stm,Cx5	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	Skl4R3/Stm,Cx5	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	Skl6/Stm,Cx5	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	Skl6R1/Stm,Cx5	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	Stm,Cx5/Es1	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	Stm,Cx5/Ey,A14	Manhattan
Stm,Cx5	Stm, Cephalothorax 5, cis	2	Stm,Cx5/Ey; s/s	Manhattan
Stm,Ns	Stm, Narrow sternellum (cis)	2	Stm,Ns/Es1	Manhattan
Stm-Es1/+NDJ	Non-disjunction	?	Stm-Es1/+NDJ	Manhattan
Stm-Skl4-Es/+ NDJ	Non-disjunction	?	Stm-Skl4-Es/+ NDJ	Manhattan
Stm-Skl6/+NDJ	Non-disjunction	?	Stm-Skl6/+NDJ	Manhattan
StmR1	Stm revertant 1	2	StmR1/Es1	Manhattan
StmR2	Stm revertant 2	2	StmR2/Es1	Manhattan
StmR5	Stm revertant 5	2	StmR5/Es1	Manhattan
StmR6	Stm revertant 6	2	StmR6/Es1	Manhattan
T(Y;3)	Translocation Y-3	Y;3	T(Y;3)	Manhattan
T(Y;4)	Translocation Y-4	Y;4	T(Y;4)	Manhattan
T. brevicornis	Tribolium brevicornis	NA	T. brevicornis	Manhattan
T. confusum (apt,mas,sti)	T.c. with apt, mas, sti	?	T. confusum (apt,mas,sti)	San Bernadino
T. confusum (b,au,lod,p)	T.c. with b,au,lod,p	?	T. confusum (b,au,lod,p)	San Bernadino
T. confusum (PRC)	Tribolium confusum	NA	T. confusum (PRC)	P.R. China
T. freemani	Tribolium freemani	NA	T. freemani	Japan
T. madans	Tribolium madans	NA	T. madans	Manhattan
tar	anterior melanotic stink glands	2	tar	Manhattan
tib	tibialess (from ab)	9?	tib	Manhattan
Tiw-1	?	NA	Tiw-1	India
Tiw-1 (iso 43)	Tiw-1 isoline	NA	Tiw-1 (iso 43)	India
Tiw-1(iso 43) pink	pink eye from Tiw-1	NA	Tiw-1(iso 43) pink	India
tr	trembler	2;4	Es/tr	Manhattan
tr	trembler	2;4	tr	Manhattan
ub	unbuckled T1 epimera	2	Ey,ub/Es,ub	Manhattan
ub	unbuckled	2	ub	Manhattan
ub	unbuckled	2	ub, ab	Manhattan
ub	unbuckled	2	ub,g	Manhattan
ub	unbuckled	2	ub,pas30	Manhattan
ub	unbuckled	2	Quint(ub,mxp,apt,mas,pas)	Manhattan
ue	unsclerotized elytra	?	ue	Manhattan
ue	unsclerotized elytra	?	ue,ab,msg,p,mxp,apt,pas30	Manhattan
Utx(New)	Ultrathorax (New)	2	Utx(New)	Manhattan
Utx1	Ultrathorax	2	A10,mxpA10/Utx1,mxp,apt	Manhattan

Utx1	Ultrathorax	2	lp69/Utx1,mxp,apt	Manhattan
Utx1	Ultrathorax	2	Utx1,mxp,apt/mxpX9,Es1	Manhattan
Utx1	Ultrathorax	2	Utx1/Es	Manhattan
Utx1	Ultrathorax	2	Utx1/Utx1	Manhattan
Utx2,Stm	Ultrathorax 2, Stm (cis)	2	Utx2,Stm/Es1	Manhattan
vwe	vestigial wings and elytra	2	vwe/Dch3	Manhattan
vwe	vestigial wings and elytra	2	vwe/Es1	Manhattan
vwe	vestigial wings and elytra	2	vwe/Stm,Ag4	Manhattan
w	white eye	4	w	San Bernadino
X(ab-1s)	Lethal revertant from ab	9	Dch3/X(ab-1s)	Manhattan
X(ab-2s)	lethal revertant from ab stock	3	3P2/X(ab-2s)	Manhattan
X-31	lethal 31	2	X-31/Dch3	Manhattan
X-31 pearl s.l.	lethal 31 with pearl	2	X-31 pearl s.l./Dch3	Manhattan
X-47	lethal 47	2	X-47/Stm,Ag4	Manhattan
X-83	Lethal 83	2	X-83/Stm,Ag4	Manhattan

SUE HAAS.

bge bug-eyed
cfl-2 confusum-like
(See descriptions in this issue of TIB)

Ga-1 stock
Bamp31 stock

SAN BERNARDINO, CALIFORNIA
CALIFORNIA STATE UNIVERSITY
BIOLOGY DEPARTMENT

I. Tribolium anaphe
1. Wild
2. Splprps (1)

II. Tribolium audax

III. Tribolium brevicornis

1. Wild	Riverside, 1969
2. Wild	Idaho 1975
3. Wild	San Bernardino, 1977
4. spl	

IV. Tribolium castaneum

A. Wild type strains

1. Chicago	Park, 1955
2. Consejo	Spain, a968
4. Davis	Davis, Ca, 1961
6. Florida	Bell, 1970
8. McGill	Stanley, 1958
10. PIL	?
12. Sacramento	1961
14. Texas	1958
16. Veracruz	Mexico, 1963
17. Virginia	
19. Synthetic 1 (has s)	Prepared 1958
20. Synthetic 2 (no body color)	Prepared 1958
23. New York UPF	1976
24. San Bernardino	1976
25. CS-4 (from New York)	1976

B. Mutants

1. Sex-linked

26. dve--divergent elytra	Chazy, 1959
30. pd--paddle	Park, 1955
34. pte	Berkeley, 1965
36. py--pygmy	Chazy, 1959
38. r--red	Chazy, 1959
39. r^{D} --red	Berkeley

54. pd, r^{r}--paddle, red
55. py, r, M --pygmy, red, red modifier
59. r, sp--red spotted
61. pd, pte--paddle, platinum eye

Autosomal

63. p--pearl II New York 1976
Pk
64. p --pink II Chazy, 1959
65. p pearl II Park 1955
S
66. p pearl II
76. au--aureate III
78. b--black III
S-1
81. b -- black, Brazil
82. b--black Chicago 1955
84. b--black McGill 1959
85. b--black McGill via New York, 1976
86. b--black NASA 1959
88. b--black synthetic (Chicago/McGill)
90. Chr--Charcoal III
91. lod p--light ocular diaphragm, pearl III,II
94. msg--melanotic stink glands III
96. mt--mottled III
t
98. b --tawny III
105. fas-2--fused antennal segments-2 IV
107. ap, ju--antennapedia, juvenile urogomphi
113. s--sooty (Berkeley synthetic background) IV
114. s--sooty (New York) IV
135. j--jet V
AS
136. j --jet V
139. mc--microcephalic V Chazy, 1959
140. mc-1 microcephalic-1 (eyeless) V Hayward 1967
143. fas-3a fused antennal segments 3a V Berkeley, 1963
148. m--maroon V Purdue 1970
150. rb--ruby V Berkeley, 1962
156. Mo--Microphthalmic VI Chazy, 1959
162. sa=ca--short antenna VII Cold Sprg. Hbr. 1960
165. c--chetnut VII Purdue, 1962
168. ju-7--juvenile urogomphi VII-IV Purdue
170. ble--blistered elytra VII Berkeley 1962
173. c, Rd VII,II Corvallis 1975
S
180. ap --antennapedia VIII Berkeley 1962
D
186. sq --squint VIII Chazy 1959
189. apt--alate prothorax IX Berkeley 1963
192. ptl--prothoraxless IX Chazy 1959
194. ppas--partially pointed abdominal sternites Berk. 1963
196. mas--missing abdominal sternites II Berkeley 1964
228. Dch--Dachs II San Bernardino 1976
230. fas-1--fused antennal segments-1 Chazy 1959
233. imp--incomplete mesothoracic projections
238. mxp--maxillopedia II berkeley 1965
240. Npp--Non-punctate prothorax, a phenodeviant

245. pec--pectinate
252. sc--scar Purdue
259. w--white Purdue
261. fas-8--fused antennal segments-8
271. Gi--Giant PIL
278. la--long abdomen PIL
280. Veracruz small
288. fas-9 fused antennal segments-9 San Bernardino, 1975
295. pd,p--paddle, pearl I, II
296. pd,p,b--paddle, pearl black I, II, III
297. sp,p--spotted, pearl I, II
299. py,i,p--pygmy, ivory, pearl I, II, II
301. p, au, lod--pearl, aureate, light ocular diaphragm II, III, III.
302. p, au, mc--pearl, aureate, microcephalic II, III, V
303. p,b--pearl, black (II, III)
304. p,au,lod,msg--pearl, aureate, light ocular diaphragm, melanotic stink glands (II, III, III, III)
306. p,b,pe--pearl, black, pointed elytra (II, III,?)
308. p,mc--pearl, microcephalic II, V
310. p,s--pearl, sooty II, IV
312. p,j,Npp--pearl, jet, Non-punctate prothorax II, V
313. p,apt,Mo--pearl, alate prothorax, Microphthalmic II, II, VI.
315. p,mas--pearl, missing abdominal segments II, II
316. p, knp--pearl, knobby prothorax II, II
317. p,aa--pearl, abbreviated appendages II, V
322. p,Fas-4,b--pearl, Fused antennal segments-4, black II, ?, III
415. mxp,s--maxillopedia, sooty II, IV
416. au, s--aureate, sooty III,IV
417. h, s--hazel, sooty III, IV
428. c, Npp--chestnut, Nonpunctate prothorax VII, ?
430. au,Npp--aureate, Nonpunctate prothorax III, ?
436, au,mc--aureate, microcephalic III, V
442. Df,s,Mo--Deformed, sooty, Microphthalmic ?, IV, VI
444. i,lod,Mo--ivory, light ocular diaphragm, Microphthalmic II, III, VI
445. i,ppas-ivory, partially pointed abdom. sternites II, ?
448. Chr,ap--Charcoal, antennapedia III, VIII
450. au,ble--aureate, blistered elytra III, VII

ELL Pk

454. p /p II
462. mas, mc--missing abdominal segments, microcephalic II,V
469. i,lod--ivory, light ocular diaphragm II,III
470. lod,rb--light ocular diaphragm, ruby III, ?
473. fas-6--fused antennal segments-6

V. Tribolium confusum

Wild type strains

1. Chicago Park, 1955

2. Chicago via Sokal, 1975
3. McGill via McDonald
4. McGill Stanley, 1958
5. New York 1961
6. Sacramento
7. San Bernardino 1968
8. Yugoslavia 1975

Synthetic strains
1. Berkeley

Mutant strains

apt--alate prothorax I
apt,fas-2--alate prothorax, fused antennal segments-2
b-black III
b,cas,p--black, creased abdominal segments, pearl
b,lod,p--black, light ocular diaphragm, pearl
b,p--black, pearl
b,rus--black, ruby spot
b,rus,spl--black, ruby spot, split
b,twa--black, twisted abdomen
b-2--black-2
b-2/b McGill--synthetic black
bZ,rZ--black Zagreb, red Zagreb
(black strains from Carlisle, Pa., Chicago, Donner lab, Georgia, McGill, Sault Ste. Marie, Winnipeg and Yugoslavia)
b-Chicago/b McGill--synthetic black
b-Mcgill,fas--black, fused antennal segments
b-Mcgill,p--black, pearl
b-SSM,spl--black, split
ble--blistered elytra V
ble,e--blistered elytra, ebony V,V
car,p--carmine, pearl
cas--creased abdominal segments II
cla-claret
cru--crumpled I
dpe--dirty pearl eye II
dj--disjoined VI
dt--dent (see umb--umbilicus)
dt,p--dent, pearl
e--ebony V Chicago, 1955
(other ebony alleles)
e,fas-3--ebony, fused antennal segments-3 V, ?
e-2--ebony-2 (not allelic with e) II
e-2,fas-1--ebony, fused antennal segments-1
ele--elongated elytra
ele,fas-2--elongated elytra, fused antennal segments-2
es--eyespot I
es,fas-1--eyespot, fused antennal segments-1
es,fas,msg--eyespot, fused antennal segments melanotic stink glands I, ?, III
es,fas,sti--eyespot, fused antennal segments, sternites incomplete

eu,fas-2--extra urogomphi, fused antennal segments-2
fas-2--fused antennal segments-2 II
fas-2,lod,msg,p--fused antennal segments-2, light ocular diaphragm, melanotic stink glands, pearl II,III,III,II
fas-2,lod,p--fused antennal segments-2, light ocular diaphragm pearl II,III,II
fas-2,msg--fused antennal segments-2, melanotic stink glands II,III
fas-3--fused antennal segments-3
fro--frosted
lod,rus--light ocular diaphragm, ruby spot
msg--melanotic stink glands III
msg,rus--melanotic stink glands, ruby spot III,III
msg,twa--melanotic stink glands, twisted abdomen III,?
ov-like--overshot-like
p-pearl II
p-Slough-pearl
R
p --pearl riboflavinless II
r-red I
r,sh--red, short elytra
U
r --red
Z
r --red from Zagreb
rby--ruby
rus--ruby spot III
sh--short elytra (Berkeley)
sh,sp,twa--short elytra, split, twisted abdomen
sp--split III
sp-1--split-1
twa--twisted abdomen
thu--thumbed IV
S
thu --an allele of thu. IV
thu, Xl--thumbed, Extra large
umb--umbilicus

VI. Tribolium destructor

VII. Tribolium freemani

VIII. Tribolium madens

A. Sokoloff

SAVANNAH, GEORGIA
STORED-PRODUCT INSECTS RESEARCH AND DEVELOPMENT LABORATORY

I. Wild type strains

A. Lepidoptera

1. Cadra cautella (Walker)	N.C.
2. Plodia interpunctella (Hubner)	Tifton, Ga.
3. Sitotroga cerealella (Olivier)	Modesto, Ca.
	Manhattan, Ka
	Can., and Durham, N.H.

b. Coleoptera

1. Attagenus megatoma (Fab.)	CSMA strains
2. Callosobruchus maculatus (Fab.)	Fresno, ca.
3. Cryptolestes ferrugineus (Stephens)	S. Carolina
4. Lasioderma serricorne (Fab.)	Unknown
5. Oryzaephilus mercator (Fauvel)	Unknown
6. Oryzaephilus surinamensis (L.)	Manhattan, Kan.
7. Rhyzopertha dominica Fab.)	Unknown
8. Sitophilus granarius (L.)	Manhattan, Kan.
9. S. oryzae (L.)	Ark., Calif., Kan., La.
10. S. zeamais Motchulsky	Estill, S.C.
11. Stegobium paniceum (L.)	Madison, Wis.
12. Tribolium castaneum (Herbst)	Unknown
13. Tribolium confusum duVal	Manhattan, Kan.
14. Trogoderma glabrum (Herbst)	Madison, wis., Riverside, Ca.

II. Mutant strains. None

Richard T. Arbogast, Laboratory Director.

South Orange, New Jersey
Seton Hall University
Department of Biology

T. castaneum

Wild Type Strains

Seton Hall-1

McGill, via California State

Synthetic Strains

Pearl Foundation, via Purdue University

Black Foundation, via Purdue University

Mutant Strains

Paddle (pd)	via Cal State U., S.B.
Red (R^{Ho} / R^{ho})	Via Cal State U., S.B.
White (w)	Via Cal State U., S.B.
short antenna (ca)	Via Oregon State
Short antenna (Sa)	Via Purdue University

Tribolium confusum Via Carolina Biological Supply

Eliot Krause

Storrs, CT 06269
University of Biology

Tribolium castaneum
Ga-1
sooty
Charcoal
RR strain from Costantino
Oryzaephilus surnamensis

J.S. Bancroft

ST. PAUL, MINNESOTA
UNIVERSITY OF MINNESOTA
DEPARTMENT OF ENTOMOLOGY, FISHERIES AND WILDLIFE

I. Wild type strains

A. Coleoptera strains

Dermestidae

Attagenus megatoma (F.)	Madison, Wis., 1975, Savannah, Ga. 1974
Trogoderma variabile Ballion	field collected, Mn. 1972

Cucujidae

Oryzaephilus surinamensis (L)	
Oryzaephilus mercator (Fauvel)	
Cryptolestes pusillus (Schoenherr)	Manhattan Ka. 1967
Cryptolestes ferrugineus (Stephens)	Unknown

Silvanidae

Ahasverus advena Waltl.	Minnesota

Tenebrionidae	
Cyaneus angustus (LeConte)	Winnipeg; Minnesota
Tribolium castaneum (Herbst)	Corvallis, Ore
Tribolium confusum duVal	Unknown
Tenebrio molitor	Carolina Biological, 1984
Anobiidae	
Lasioderma serricorne (Fab.)	Savannah, Ga.
Bostrichidae	
Rhizopertha dominica (F.)	Manhattan, Ka.
Prostephanus truncatus (Horn)	Unknown
Curculionidae	
Sitophilus granarius (L.)	Unknown
S. oryzae (L.)	"

B. Lepidoptera

Pyralidae	
Anagasta kuehniella (Zeller)	Savannah, Ga.
Gelechiidae	
Sitotroga cerealella (Oliver)	Savannah, Ga.

(Ed.)

St. Paul, Minnesota 55108
University of Minnesota
Department of Entomology
Stored-Grain Pest Management Program

Eight species of stored-product beetles and two species of moths are maintained in the laboratory. These species include: Angoumois grain moth, flat grain beetle, Indian meal moth, larger brain borer, lesser grain borer, merchant grain beetle, red flour beetle, red flour beetle, rusty grain beetle, rice weevil, and sawtoothed grain beetle.

The Angoumois grain moth was obtained in June 1993 from Community Research Service, Kentucky State University, Kentucky. All other species were obtained in January 1992 from the Department of Entomology, Kansas State University, Manhattan, Kansas. Except for the merchant grain beetle, all species originated from farm-stored grain. The origin of merchant grain beetles is unknown.

Areas of research:

Developing and validating sampling schemes for insects associated with farm-stored grain.

Evaluating nonchemical alternatives for suppressing stored-grain traits.

Modeling population trends of insects from life-history traits.

Bhadriraju Subramanyam, Ph. D.

WASHINGTON, D.C. 20204
DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
DIVISION OF MICROBIOLOGY

Coleoptera

Anobiidae
Stegobium paniceum (L.)

Anthribidae
Araecerus fasciculatus (Deg.) (poor condition; may be dead).

Bostrichidae
Rhyzopertha dominica (F.)

Bruchidae
Acanthoscelides obtectus (Say)

Cleridae
Necrobia rufipes (Deg.)

Cucujidae
Ahasverus advena (Waltl)
Cryptolestes ferrugineus (Steph.). Poor condition, may be dead.
C. pusillus (Schon.)
C. turcicus (Grouv.)
Oryzaephilus surinamensis (Linnaeus)

Curculionidae
Sitophilus granarius (L.)
S. zeamais Motschulsky

Dermestidae
Anthrenus flavipes LeC. Weak culture
Anthrenus verbasci (Linnaeus)
Dermestes maculatus De Geer
Trogoderma variabile Ballion

Ostomidae
Gibbium psylloides (Czemp.)

Silvanidae
Ahasverus advena (Waltl.)
Oryzaephilus surinamensis

Tenebrionidae
Alphitobius diaperinus (Panz.)
Gnathocerus maxillosus (F.)
Palorus ratzeburgi (Wissm.)
Tribolium brevicornis (LeConte)
T. castaneum (Herbst)
T. confusum Duv.
T. destructor Uytt.--weak culture, may be diseased.

I. madens (Charpentier)

M. Nakashima

AUSTRALIA

Burnley, Victoria
Victoria Plant Research Institute
Department of Agriculture

COLEOPTERA

Tribolium castaneum

Wild type strains
Malathion specific resistant strain
Malathion non-specific strain

Tribolium confusum

Wild type strains
Malathion specific strain

Oryzaephilus surinamensis

Wild type strain
Malathion resistant strain

Oryzaephilus mercator

Alphitobius diaperinus

Cryptolestes ferrugineus

Gnathocerus cornutus

Gnathocerus maxillosus

Latheticus oryzae

Rhyzopertha dominica

Sitophilus granarius

Sitophilus oryzae

Sitophilus zeamais

Tenebroides mauritanicus

LEPIDOPTERA

Ephestia cautella

Ephestia figulella

Galleria mellonella

Plodia interpunctella

P. Williams

Indooroopilly, Queensland 4068, Australia
Queensland Department of Primary Industries
Plant Protection Unit

Coleoptera

Oryzaephilus surinamensis

Wild type strains		
VQS 48	insecticide susceptible	Victoria
QQS 42	fenitrothion susceptible	Queensland
QQS 115	chlorpyrifos-methyl-R a	Queensland

Rhyzopertha dominica

Wild type strains		
QRD 369	phosphine-resistance	Queensland
QRD 14	insecticide susceptible	Queensland
QRD 2	multiresistant	Queensland
QRD 63	multiresistant	Queensland
QRD 318	pyrethroid-resistant	Queensland

Sitophilus oryzae

Wild type strains		
LS 2	insecticide susceptible	Queensland
QSO 56	multi-resistant	Queensland
CSO 231	multi-resistant	W. Australia
QSO 388	phosphine-resistant	Queensland

Tribolium castaneum

Wild type strains		
QTC 4	insecticide susceptible	Queensland
QTC 279	pyrethroid insecticide resistant	Queensland
QTC 285	multi-resistant, composite strain	Queensland
CTC 12	non-specific malathion resistant	Queensland
QTC 34	malathion specific-resistant	Queensland
QTC 320	phosphine-resistant	Queensland

Lepidoptera Queensland

Ephestia cautella Wild

Patrick J. Collins, Senior Entomologist

Unit of general and applied Zoology
Faculty of agriculture, Gembloux , Belgium
2, Passage des Déportés, 5030 Gembloux, Belgium

Insect stock list (11/8/96)

Coleoptera

Callosobruchus maculatus	Senegal, 1989
Cryptolestes ferrugineus	Senegal, 1995
Oryzaephilus surinamensis (6 wild strains)	Belgium, 1991
Prostephanus truncatus	Togo, 1993
Rhizoperta dominica	Canada, 1991
Sitophilus granarius (6 wild strains)	Belgium, 1991
Sitophilus zeamais	Senegal, 1995
Tenebrio molitor	Belgium, 1995
Tribolium castaneum (3 strains)	
Asm (sensitive)	Abidjan, 1989
Prm (malathion specific-resistant)	Philippines, 1989
Bj (black, malathion specific-resistant)	Belgique, 1993

LUDOVIC ARNAUD

ECOLOGY OF FIELD AND STORED PRODUCT PESTS SECTION
AGRICULTURE AND AGRI-FOOD CANADA
WINNIPEG RESEARCH CENTRE
195 DAFOE ROAD
WINNIPEG, MANITOBA, R3T 2M9

STOCKLIST

	SPECIES	ORIGIN	
	COLEOPTERA		
1.	*Acanthoscelides obtectus*	Phillips, Wis	1993
2.	*Ahasverus advena*	Argyle, MB	1991
3.	*Callosobruchus maculatus*	Phillips, Wis	1993
4.	*Cryptolestes ferrugineus*	Manitoba, MB	1991
5.	*Cryptolestes pusillus*	Lac du Bonnet, MB	1988
6.	*Cryptolestes turcicus*		1971
7.	*Cynaeus angustus*	Minnesota, MN	1982
8.	*Lasioderma serricorne*	Winnipeg, MB	1984
9.	*Liposcelis bostrychophilus*	Winnipeg, MB	1994
10.	*Oryzaephilus mercator*	Winnipeg, MB	1994
11.	*Oryzaephilus surinamensis*	Landmark, MB	1991
12.	*Prostephanus truncatus*	Mexico City, Mexico	1977
13.	*Rhyzopertha dominica*	Manitoba	1993
14.	*Sitophilus granarius*		
15.	*Sitophilus oryzae*	Coal Lake, AB	1992
16.	*Sitophilus zeamais*		
17.	*Stegobium paniceum*	Winnipeg, MB	1993
18.	*Tenebrio molitor*	Winnipeg, MB	1980
19.	*Tribolium audax*		
20.	*Tribolium castaneum*	Manitoba	1991

	SPECIES	ORIGIN	
The following *Tribolium castaneum* mutant strains were received in November, 1985 from Dr. Sokoloff's laboratory at California State University.			
21.	Culture S38	red eye	
22.	Culture S351	red eye, pygmy, fused antennal segments	
23.	Culture S156	microphthalmic	
24.	Culture S136	jet (dark body)	
25.	Culture S113	sooty (dark body)	
26.	Culture S63	pearl eye	
27.	Culture S165	chestnut eye	
28.	Culture S148	maroon eye	
29.	Culture S38	paddle (antennae fused, flattened)	
30.	*T. castaneum*	abbreviated appendages (aa), missing abdominal *sternites* (mas)	
31.	*T. castaneum*	Rio Desago Malathion resistance	
The following mutant strains of *Tribolium castaneum* have had no linkage analysis:			
32.	malathion-specific resistance		
33.	black body and pearl eyes		
The following mutant strains of *Tribolium confusum* have had no linkage analysis.			
34.	red eyes		
35.	black body		
36.	*Tribolium confusum*	Winnipeg, MB	1994
37.	*Tribolium madens*		
38.	*Trogoderma variabile*		
39.	*Typhaea stercorea*	Manitoba	1991
	LEPIDOPTERA		
1.	*Plodia interpunctella*	Winnipeg, MB	1990
2.	*Sitotroga cerealella*	Kansas	1982

Dr. Noel D.G. White
Section Head

COLOMBIA

SANTA FE DE BOGOTA, D.C.,
UNIVERSIDAD NACIONAL DE COLOMBIA
FACULTAD DE CIENCIAS
DEPARTAMENTO DE BIOLOGIA
APDO. AEREO #14490

Tribolium castaneum

I. Wild type strains

NAME	ORIGIN	DATE
1. ABBC	Synthetic, Bogota	1982
2. Apulo	Apulo (Cund.) Col.	1982
3. Bogota	Inst. Publ. Health, Bogota, Col.	1978 1981
4. Bucaramanga	Bucaramanga, (Sant.)	1981
5. Cartagena	Cartagena, Bol., Col	1980
6. Fusa	Fusagasuga, Cund. Col	1986
7. Honda	Honda, tol. Col.	1986

II. Domestic mutants

Mutant strains discovered in Colombia

NAME	SYMBOL	LINKAGE GROUP	ORIGIN	DATE OF ENTRY
8. Antennapedia	ap N	VIII	Bog.	1981
9. Argentum eyes	ae	I	Bog	1993
10. Bifurcated antenna	ab N	II	Bog.	1980
11. Black	b	III	Bog.	1983
12. colossal pupae	cp b	?	Bog.	1993
13. Charcoal	Chr	III	Bog.	1979
14. Disjuncted elytra	ed	?	Bog.	1990
15. Fused antennameres	af	?	Bog.	1980
16. Glass legs	pv	?	Bog.	1980
17. Globose antenna	Ag	VII	Bog.	1989
18. Light eyes-1	oc	?	Bog.	1990
19. Light eyes-2	?	?	Bog.	1990
20. Light eyes-3	?	?	Bog.	1991
21. Light eyes-4	?	?	Bog.	1993
22. Metathoracic scar	sc V	III	Bog.	1983
23. Miniature appendaged	ma	I	Bog.	1981
24. Narrow eyes	oje	?	Bog.	1980
25. Red eyes	or	?	Bog.	1986
26. White eye	obl	IV	Bog.	1982

III. Imported mutants from Tribolium Stock Center, 1985

27. Antennapedia	ap D	VIII	33. Pearl eye	p II
28. Black	b	III	34. Platinum eye	pte I
29. Charcoal	Chr	III	35. Pygmy	py I
30. Miniature appendaged	ma	I	36. Short antenna	Sa VII
31. Microcephalic	mc	V	37. Sooty	s IV
32. Microphthalmic	Mo	VI		

Fernando Nunez del Castillo

DENMARK

LYNGBY
STATENS SKADEDYRLABORATORIUM
(DANISH PEST INFESTATION LABORATORY)

Anthrenus museorum
A. vorax
Attagenus smirnovi
A. unicolor (piceus)
A. woodroffei
Dermestes hemorrhoidalis
Lasioderma serricorne
Oryzaephilus surinamensis
Prostephanus truncatus
Ptinus tectus
Sitophilus granarius
S. oryzae
Stegobium (Sitodrepa) paniceum
Tenebrio molitor
Thylodrias contractus
Tribolium confusum
T. destructor
Trogoderma angustum
T. granarium

K. Arevad and H. Mourier

FRANCE

VILLEURBANE (LYON) RHONE
INSTITUT NATIONAL DES SCIENCES APPLIQUEES
LABORATOIRE DE BIOLOGIE

A. Wild type strains

1. Sitophilus granarius L.

2. S. oryzae L.
   a. FB strain (La Reunion)
   b. SFr strain (lyon) (56,500+3,000 ovarian symbiotes)
   c. W strain (Villeurbane) (22,700+1500 ovarian symbiotes)

3. S. zea-mais Mots--from PIL, Slough

B. Selected lines of Sitophilus oryzae

   1. SS/Sfr strain:aposymbiotic strain (0 ovarian symbiotes) obtained from Sfr
   2. LL strain (slow development)(42,000+3000 ovarian symbiotes)
   3. RR strain (fast development) 88,000+5000 ovarian symbiotes)

P. Nardon
(No updated list available, Ed.).

ZOOLOGISCHES INSTITUT I
(ZOOLOGIE) DER ALBERT LUDWIGS UNIVERSITAT
D 78 FREIBURG IM BREISGAU
KATHARINENSTRASSE 20

Wild type strains
1. Oryzaephilus surinamensis Freiburg
2. Tribolium castaneum San Bernardino
3. T. confusum San Bernardino

Mutant strains (All from San Bernardino)
A. Tribolium castaneum
4. alate prothorax (apt)
5. Bar eye (Be)
6. black (Brazil background)
7. black (Chicago background)
8. Dachs (Dch)
9. Fused tarsi and antennae (Fta)
10. Microphthalmic (Mo)
11. nude (nd)
12. pygmy (py)

13. short antenna (sa)
14. Short antenna (Sa-2)
15. sooty (s)
16. Spatulate antenna (Spa)
weird eggs (wd)

B. Tribolium confusum
18. black-3 (b-3)
19. ebony (e)
20. ebony-2 (e-2)
21. McGill black (McGb)

K. Sander

MUNICH,
BAYER. LANDESANSTALT FUR BODENKULTUR
UND PFLANZENBAU, ABT. PFLANZENSCHUTZ

Coleoptera

Bruchidae--Acanthoscelides obtectus (Say)

Cucujidae--Cryptolestes turcicus Grouv. Munich, 1966

Ptinidae
Gibbium psylloides (Czemp) Regensburg, 1960
Ptinus tectus (Boi.) Munich, 1972

Silvanidae

Oryzaephilus mercator (Fauv.)	Munich,	1966
O. surinamensis (L)	?	1971

Munich (cont'd)

Tenebrionidae

Gnathocerus cornutus (F.)	MUNICH,	1966
Tribolium castaneum	?	1971
T. confusum Duv.	Munich,	1960
T. destructor Uyttenb.	"	1957

Lepidoptera

Phycitidae--Ephestia kuehniella (Zell.)	"	1966

E. Naton.

GERMANY

D-80333 München
Institut fur Zoologie
Luisenstrasse 14

WILD TYPE

Tribolium castaneum

MUTANTS provided by A. Sokoloff

Tribolium castaneum
- Bar eye, sooty (Be, s)
- Black, microcephalic pearl (b,mc,p)
- Microcephalic (mc)
- Microcephalic aureate (mc, au)
- Microphthalmic (Mo)
- Squint (sq)

Tribolium confusum
- Diminished eye (dim)

Marcus Friedrich

(Note: Marcus Friedrich has finished his Ph.D thesis. He is now at the California Institute of Technology, Pasadena, California.)

Tel Aviv University ,Israel

Tribolium Stock List

(Note : TSC Tribolium Stock Center, San Bernardino, Calif.)

T.castaneum

Wild Type Strains :	Origin :
CS++ Ishaaya	Israel,before 1972
CTC-12 (Insecticide resistant)	Slough (England), 1977
Kano C (Malathion resistant)	Slough (England), 1977
Mutant Strains :	
CS bb	Stony brook, 1970
EU++ (extra urogomphi)	Derived from CSbb, 1973
CSmc (microcephalic)	Derived from PPxbb, 1979
CS Paddle	TSC, 1988
CS Pearl	TSC, 1977
CS Pygmy	TSC, 1979

T.confusum

Wild Type Strains :	
CF Chicago	TSC, 1977
CF Tarovet	Israel, 1994
Mutant Strains :	
CF bb	Stony Brook, 1970
CF xl (extra large)	TSC, 1979

T.brevicornis

++ (Riverside)	TSC, 1979

T.freemani

Japan, 1982

DAVID WOOL

INDIA

NEW DELHI
INDIAN AGRIC. RESEARCH INSTITUTE
DIVISION OF ENTOMOLOGY
INSECT GENETICS LAB.

STOCK LIST

STRAIN	RESIST LEVEL	REARING MEDIA
1. Malathion-resist.	>x200	common wheat flour charged with tech malathion.
2. lindane-resist.	>X100	c. w. f. charged with tech. lindane
3. DDT-RESISTANT	>x100	c.w.f. charged with tech ddt.
4. pirimiphosmethyl resistant	>X100	C.W.F. CHARGED WITH tech. pirimiphosmethyl
5. phosphine-resistant	> 6.3	c.w.f.
6. delta-methrin resist	>2819.3	cwf chargedwwith tech deltamethrin
7. fenitrothion-resist.	>25.96	c.w.f.
8. susceptible	-	c.w.f.
9. black mutant	-	"

Triboliun confusum

10. susceptible	-	c.w.f.
11. nigrat- melanic mutant	-	"

J.D. Saxena.

JAPAN

NATIONAL FOOD RESEARCH INSTITUTE
MINISTRY OF AGRICULTURE, FORESTRY AND FISHERIES
2-1-2 KANNONDAI, YATABE-MACHI
TSUKUBA-GUN, IBARAKI-KEN 305

Psocoptera	
Liposcelidae	
Liposcelis bostrychophilus Badonel	Wild
Liposcelis entomophilus (Enderlein)	Wild
Trogiidae	
Lepinotus reticulatus Endelein	Wild
Coleoptera	
Anobiidae	
Lasioderma serricorne (Fabricius)	Wild
Stegobium paniceum (L.)	Wild
Ptinidae	
Gibbium equinoctiale Boieldieu	Wild
Bostrichidae	
Rhyzopertha dominica (Fabricius)	Wild
Dinoderus minutus (Fabricius)	Wild
Cucujidae	
Cryptolestes turcicus	Wild
Cryptolestes pusilloides (Steel & Howe	Wild
Silvanidae	
Oryzaephilus surinamensis (L.)	Wild
Tenebrionidae	
Alphitobius diaperinus (Panzer)	wild
Gnathocerus cornutus (Fabricius)	Wild (Okayama str.)
Palorus ratzeburgi (Wissmann)	Wild
Tribolium castaneum (Herbst)	Wild
T. confusum Jacquelin du Val	Wild
T. freemani Hinton	Wild
Tenebrio molitor L.	
Bruchidae	
Callosobruchus chinensis (L.)	Wild
Anthribidae	
Araecerus fasciculatus Degeer	Wild
Rhynchophoridae	
Sitophilus zeamais Motschulsky	Wild
Sitophilus oryzae (L.)	Wild
Lepidoptera	
Pyralidae	
Ephestia cautella (Walker)	Wild
E. kuhniella (Zeller)	Wild
Plodia interpunctella	Wild
Corcyra cephalonica	Wild
Gelechiidae	
Sitotroga cerealella (Olivier)	Wild

H. Nakakita H. Ikenaga

OKAYAMA
LABORATORY OF APPLIED ENTOMOLOGY
COLLEGE OF AGRICULTURE
OKAYAMA UNIVERSITY

1. Wild type strains

COLEOPTERA

1.	Alphitobius diaperinus	Miyazaki
2.	Callosobruchus chinensis	Okayama
3.	C. maculatus	
4.	Gnathocerus cornutus	Miyazaki
5.	Lasioderma serricorne	Okayama
6.	Latheticus oryzae	Miyazaki
7.	Oryzaephilus surinamensis	Miyazaki
8.	Palorus ratzeburgii	Miyazaki
9.	P. subdepressus	Miyazaki
10.	Rhyzopertha dominica	Miyazaki
11.	Sitophilus oryzae	Okayama
12.	S. zeamais	Okayama
13.	Tenebrio molitor	Okayama
14.	Tenebroides mauritanicus	Okayama
15.	Tribolium castaneum	Miyazaki
16.	T. confusum	Miyazaki
17.	T. freemani	

HYMENOPTERA

1.	Anisopteromalus calandrae	Okayama
2.	Chaetospila elegans	Okayama
3.	Lariophagus distinguendus	Okayama

Toshiharu Yoshida

INSTITUTE OF BIOLOGICAL SCIENCES
UNIVERSITY OF TSUKUBA
SAKURA-MURA, IBARAKI
300-31 JAPAN

Bruchidae

Callosobruchus chinensis

13 wild type strains from different localities in Japan and abroad

Black colored mutant derived from Shusenji strain.

cC Mainland China
fC Fukushima, Japan
hC Hirosaki, Japan
h1C Hirosaki, Japan

jC Kyoto, Japan, 1936
mC Morioka, Japan
nC Niigata, Japan, 1964
pC Punjab, India
sCbl Shusenji black mutant
tC Tokyo (Nishigahara, Nat. Inst. Agr.(, Japan
taC Tsukuba, Japan
taC2 Tsukuba, Japan
tsC Tsukuba, Japan
yC Taisha, Japan

C. maculatus
12 wild type strains from different localities in the world.
aQ U.S.A. (probably Louisiana).
bQ Burma
cQ Fresno Lab., USDA, Calif., U.S.A.
eQ Thailand
fQ Thailand
oQ Ohio, U.S.A.
rQ
tQ Tel Aviv, Israel (Dept. Plant Prot., Stored Prod. Res. Res. Lab.
kQ Kyoto, Japan
mQ Kansas State Univ., Manhattan, KS, U.S.A.
sQ Savannah Lab, USDA, georgia, U.S.A.

C. analis From United Kingdom
C. phaseoli From United Kingdom
Zabrotes subfaciatus From Africa
Acanthoscelides obtectus From California, U.S.A.

Hymenoptera
Braconidae
Heterospilus prosopidis from Hawaii, U.S.A.
Pteromalidae
Anisopteromalus calandrae, Japan
Chaetospila elegans from United Kingdom
Dinarmus basalis from India

K. Fujii

PAKISTAN

LAHORE
University of the Punjab (New Campus)
Department of Zoology

Tribolium castaneum
a) Pak Wild type strain
b) CTC 12 Malathion resistant
c) FSS II Multi organophosphorus susceptible

PEOPLE'S REPUBLIC OF CHINA

Beijing
Beijing Agricultural University
Dept of Animal Science

Tribolium castaneum

Wild type strains

1. Base population for quantitative genetics, Guelph, 1987.
2. Inbreeding line--Beijing, 1987

Mutant strains: pygmy

1. Base population maintained with no artificial selection and minimum of inbreeding--Guelph, 1987
2. Inbreeding line--Beijing, 1987.

Lao Zhang

SPAIN

MADRID
INSTITUTO NACIONAL DE INVESTIGACIONES AGRARIAS
DEPARTAMENTO DE GENETICA CUANTITATIVA Y MEJORA ANIMAL

Tribolium castaneum

A. wild type strains

1. Consejo	C.S.I.C. Madrid, Spain	1964
2. Purdue	Purdue, USA.	1964
3. Edinburgh 1	Edinburgh, Scotland	1970
4. Edinburgh 2	Edinburgh, Scotland	1970
5. Campanario	Campanario, Spain	1973
6. Coronada	La Coronada, Spain	1976
7. Andujar	Andujar, Spain	1975
8. Jerez	Jerez, Spain	1975
9. Osuna	Osuna, Spain	1975
10. Carpio	Carpio, Spain	1975
11. Jafo	Jafo, Israel	1975
12. Beer-Sheba	Beer-Sheba, Israel	1975

B. Mutant type strains

13. Black Purdue	Purdue, USA,	1964

C. Experimental lines

Originated from the "Consejo" strain and selected for egg laying performance through 42 generations

	selected for	Temperature (oC)
14. AN-I	high performance at	33
15. AN-II	" "	33
16. AF-I	" "	28
17. AF-II	" "	28
18. AT-I	" "	38
19. AT-II	" "	38
20. BN-I	low performance at	33
21. BF-I	" "	28
22. BF-II	" "	28
23. BT-I	" "	38
24. BT-II	" "	38
25. RN-I*	high cross performance at	33
26. SN-I*	" " " "	33
27. RN-II	" " " "	33
28. SN-II	" " " "	33
29. RF-I	" " " "	28
30. SF-I	" " " "	28
31. RF-II	" " " "	28
32. SF-II	" " " "	28
33. RT-I	" " " "	38
34. ST-I	" " " "	38
35. RT-II	high cross performance at	38
36. ST-II	" " " "	
37. CTD-I	high performance at diff. levels of selection	
38. CTD-II	" " " " " " "	
39. DTD-I	" " " " " " "	
40. DTD-II	" " " " " " "	
41. ETD-I	" " " " " " "	
42. ETD-II	" " " " " " "	
43. FTD-I	" " " " " " "	
44. FTD-II	" " " " " " "	

D. mutants

45. antennapedia ap, VIII	Purdue, 1964
46. diferencial Df, IV	Purdue, 1964
47. fused antennal segments-2 fas-2 IV	Sokoloff, 1968
48. ivory i ?	Purdue, 1964
49. paddle, pd i	Purdue, 1964
50. pearl p II	Sokoloff, 1968
51. pegleg pg II	Purdue, 1968
52. pygmy py I	Purdue, 1968
53. rose rs I	Purdue, 1964
54. ruby rb ?	Purdue, 1964
55. short elytra sh VIII	
56. squint sq VIII	Purdue, 1964
57. white w ?	Purdue, 1964

		w		
58.	wine	r	I	Purdue, 1968
59.	eye mutant	?		Madrid, 1967
60.	maroon	m	V	Purdue, 1977
61.	melanotic stink glands--like			Madrid, 1968
62.	sooty	s	Iv	Sokoloff, 1977
63.	chestnut	c	VII	Sokoloff, 1977
64.	microcephalic	mc	V	Sokoloff, 1977
65.	Microphthalmic	Mo	VI	Sokoloff, 1977
		Pk		
66.	pink	p	II	Sokoloff, 1977
67.	Bar eye	Be	IV	Sokoloff, 1977
68.	prothoraxless	ptl	IX	Sokoloff, 1977
69.	light ocular diaphragm	lod	III	Purdue, 1968
70.	black	B	III	Sokoloff, 1977

Tribolium confusum

A. Wild type strains

71. Coronada — La Coronada, Spain

B. Mutants

72.	creased abdominal sternites	cas	II	Sokoloff, 1968
73.	ebony-2	e-2	II	Sokoloff, 1968

Ma. C. Fuentes

UNITED KINGDOM

University of Newcastle upon Tyne
United Kingdom,
Faculty of Agriculture and Biological Sciences,
Department of Agricultural and Environmental Science, University of Newcastle upon Tyne, NE1 7RU, UK.

Species/Strains	Status	Derived from
I Wild type strains		
A. *Tribolium castaneum*		
1. Ph-1	malathion specific resistant	Dr. Freeman, NRI, UK
2. FSS-II	malathion susceptible	Central Science Laboratory, Sand Hutton, York, UK.
B. *Tribolium confusum*		
1. *Tribolium confusum*	malathion susceptible	Central Science Laboratory, Sand Hutton, York, UK.
C. *Sitophilus granarius*		
1. 1022 A	lindane resistant	Central Science Laboratory, Sand Hutton, York, UK.
2. *Sitophilus granarius*	lindane susceptible	Central Science Laboratory, Sand Hutton, York, UK.
D. *Sitophilus oryzae* (L.)		
1. *Sitophilus oryzae* (L.)	Susceptible	Central Science Laboratory, Sand Hutton, York, UK.

PREPARED BY F.M. BUGHIO, A. RAUF AND R.M. WILKINS

Stock Lists

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Mrs C Trowe
Central Science Laboratory
London Road
SLOUGH, Berkshire, SL3 7HJ UK
Fax: 0753 824058
International code +44 -753 824058

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Contacts

Mrs C Trowe or Mrs S Henderson
Central Science Laboratory,
MAFF, London Road, Slough
Berks, SL3 7HJ UK

Telephone : 0753 534626
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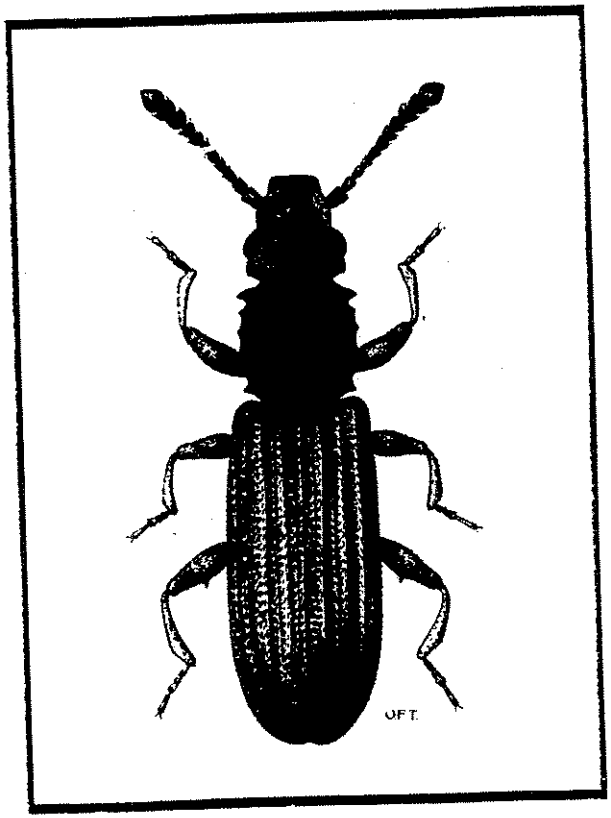
CENTRAL SCIENCE LABORATORY

Insect Cultures



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Coleoptera

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Anthrenus sarnicus
Anthrenus verbasci
Attagenus brunneus
Attagenus cyphonoides
Attagenus fasciatus cinnamomeus
Attagenus insidiosus
Attagenus pellio
Attagenus rufiventris
Attagenus smirnovi
Attagenus unicolor canadensis
Attagenus unicolor japonicus
Attagenus unicolor simulans
Attagenus unicolor unicolor
Attagenus woodroffei
Attagenus fasciatus fasciatus
Callosobruchus maculatus
Carpophilus dimidiatus
Carpophilus dimidiatus pearl-eye mutant
Carpophilus hemipterus
Coelopalorus foveicollis
Cryptolestes capensis
Cryptolestes ferrugineus
Cryptolestes pusilloides
Cryptolestes pusillus
Cryptolestes pusillus fuscus
Cryptolestes turcicus
Cryptolestes turcicus red-eye mutant
Cryptolestes ugandae
Dermestes ater
Dermestes frischi
Dermestes haemorrhoidalis
Dermestes lardarius
Dermestes maculatus
Dermestes maculatus pearl-eye mutant
Dermestes maculatus black-brown mutant
Dermestes peruvianus
Gibbium aequinoctiale
Gnatocerus cornutus
Gnatocerus maxillosus
Lasioderma serricorne
Lasioderma serricorne black mutant
Latheticus oryzae
Mezium affine
Mezium americanum
Niptus hololeucus
Oryzaephilus acuminatus
Oryzaephilus mercator
Oryzaephilus surinamensis
Oryzaephilus surinamensis small mutant
Palorus cerylonoides
Palorus ficicola
Palorus genalis
Palorus ratzeburgii
Palorus subdepressus
Prostephanus truncatus
Pseudeurostus hilleri
Ptinus clavipes
Ptinus exulans
Ptinus pusillus
Ptinus sexpunctatus
Ptinus tectus
Rhyzopertha dominica
Sitophagus hololeptoides
Sitophilus granarius
Sitophilus oryzae
Sitophilus zeamais
Sphaericus gibboides
Stegobium paniceum
Stethomezium squamosum
Tenebrio molitor
Tenebrio obscurus
Tipnus unicolor
Tribolium confusum
Tribolium anaphe
Tribolium audax
Tribolium brevicornis
Tribolium castaneum
Tribolium castaneum black mutant
Tribolium destructor
Tribolium freemani
Tribolium madens
Trigonogenius globulus
Trigonogenius particularis
Trogoderma angustum
Trogoderma anthrenoides
Trogoderma glabrum
Trogoderma granarium
Trogoderma grassmani
Trogoderma inclusum
Trogoderma irroratum
Trogoderma ornatum
Trogoderma sternale plagifer
Trogoderma variable
Trogoderma varium
Typhaea stercorea

Dictyoptera

Blatta orientalis
Blattella germanica
Diploptera punctata
Periplaneta americana

Lepidoptera

Ephestia cautella
Ephestia kuehniella
Galleria mellonella
Plodia interpunctella
Sitotroga cerealella
Tinea pellionella
Tineola bisselliella

Thysanura

Lepisma saccharina

Hymenoptera

Monomorium pharaonis

Psocoptera

Liposcelis bostrychophila
Liposcelis subfuscus
Liposcelis paetus
Lepinotus patruelis
Trogium pulsatorium

Hemiptera

Aphis fabae
Aphis gossypii
Brevicoryne brassicae
Macrosiphum euphorbiae
Myzus persicae
Nasonovia ribisnigri
Phorodon humuli
Rhopalosiphum padi
Sitobion avenae

Availability

Please give two weeks notice. Although most species can be supplied within two weeks, those breed slowly may take longer to supply.
We will advise you if there is likel be a delay.

CENTRAL SCIENCE LABORATORY

LONDON ROAD
SLOUGH
BERKS U K
SL3 7HJ

TEL: 44 1753 534626
FAX 44 1753 82405

Insects mentioned below are bred in controlled environmental conditions and , as far as possible, free from disease. All new stocks pass through a quarantine procedure before acceptance into the main insectary. This list was last updated January 1995. The country of origin and year of receipt at this laboratory are shown against the strains where this information is known. For some of the older strains such information is not known. Please note that some strains do not have a name, especially if only one strain of a species is held. Where more than five strains of a species are held, full details are not given. (However, full details of all mutant strains held are given). Please write to me or Carol TROWE for further details on any aspect of this list and with any requests for specimens. The latter will be met where sufficient are available, but a charge will have to be made.

CHRISTINE B MUGGLETON (Mrs)

INSECT DATABASE FOR TRIBOLIUM INFORMATION BULLETIN

Genus , species, sub-species.	Strain	Place of origin	Year received
COLEOPTERA			
Ahasverus advena	6 strains from 2 countries, many differing in their susceptibility to pesticides		
Alphitobius diaperinus	6 strains all from Britain, many differing in their susceptibility to pesticides		
Anthrenocerus australis		Britain	1933
Anthrenus flavipes			
Anthrenus flavipes seminiveus			
Anthrenus picturatus hintoni		Russia	1977
Anthrenus sarnicus	Wiltshire	Britain	1966
Anthrenus verbasci		Britain	1951
Attagenus brunneus	Canada		
Attagenus brunneus	Spain	Spain	
Attagenus cyphonoides		Tashkent	1976
Attagenus fasciatus fasciatus		New S. Wales	1972
Attagenus fasciatus cinnamomeus		Botswana	1965
Attagenus insidiosus		Kenya	
Attagenus pellio		Britain	1950
Attagenus rufiventris		Botswana	1970
Attagenus smirnovi		Kenya	1962
Attagenus unicolor canadensis		N. America	1980
Attagenus unicolor japonicus		Japan	1956
Attagenus unicolor simulans		U.S.S.R.	1976
Attagenus unicolor unicolor			pre 1958
Attagenus woodroffei	Sweden	Sweden	1978
Attagenus woodroffei	Finland	Finland	1965
Callosobruchus maculatus			
Carpophilus dimidiatus		USA	pre 1958
Carpophilus hemipterus			1962
Coelopalorus foveicollis		Trinidad	1972
Cryptolestes capensis			1961
Cryptolestes ferrugineus	24 strains all from Britain, many differing in their susceptibility to pesticides		
Cryptolestes pusilloides		Canada	1944
Cryptolestes pusillus			
Cryptolestes pusillus fuscus		Trinidad	1960
Cryptolestes turcicus			pre 1958
Cryptolestes ugandae		E. Africa	1954
Dermestes ater		Britain	1953
Dermestes frischii		Nigeria	pre 1958

Dermestes haemorrhoidalis		Britain	1962
Dermestes lardarius		Britain	pre 1958
Dermestes maculatus	Chittagong	Chittagong	1975
Dermestes peruvianus		Britain	1961
Gibbium aequinoctiale		Britain	1937
Gnatocerus cornutus			pre 1958
Gnatocerus cornutus			
Gnatocerus maxillosus			pre 1958
Lasioderma serricorne			pre 1958
Latheticus oryzae			pre 1958
Mezium affine		Britain	pre 1958
Mezium americanum			1960
Niptus hololeucus		Britain	pre 1958
Oryzaephilus acuminatus		Sri Lanka	
Oryzaephilus mercator			pre 1958
Oryzaephilus mercator	9127 Pickering	Britain	1994
Oryzaephilus surinamensis	54 strains from 4 countries, many differing in their susceptibility to pesticides		
Palorus cerylonoides		Indonesia	
Palorus ficicola	1168	Nigeria	
Palorus ficicola	1176	Nigeria	
Palorus genalis		Guyana	
Palorus ratzeburgii		Britain	1960
Palorus subdepressus		Turkey	1956
Prostephanus truncatus		Tanzania	1981
Pseudeurostus hilleri		Britain	1940
Ptinus clavipes		Britain	1954
Ptinus exulans		Britain	1971
Ptinus pusillus			pre 1958
Ptinus sexpunctatus			pre 1958
Ptinus tectus	Wild	Britain	1975
Ptinus tectus	PICL		1960
Ptinus tectus	Birkenhead	Britain	1975
Rhyzopertha dominica	7 strains from 3 countries, many differing in their susceptibility to pesticides		
Sitophagus hololeptoides		Trinidad	1972
Sitophilus granarius	11 strains from 3 countries, many differing in their susceptibility to pesticides		
Sitophilus oryzae	5 strains from 4 countries, many differing in their susceptibility to pesticides		
Sitophilus zeamais			pre 1958
Sitophilus zeamais	U.S.A.	U.S.A.	1982
Sphaericus gibboides		Britain	1976
Stegobium paniceum			1959
Stethomezium squamosum		Britain	1976
Tenebrio molitor			pre 1958

Tenebrio obscurus			pre 1958
Tipnus unicolor		Kenya	pre 1958
Tribolium anaphe		Nigeria	1956
Tribolium audax		Canada	1969
Tribolium brevicornis		U.S.A.	
Tribolium castaneum	9 strains from 3countries, many differing in their susceptibility to pesticides		
Tribolium confusum	W-44		
Tribolium confusum	Lab. susc.		
Tribolium confusum			1962
Tribolium destructor	African	Ethiopia	1968
Tribolium freemani		Japan	1980
Tribolium madens		Yugoslavia	1959
Trigonogenius globulus		Ireland	1961
Trigonogenius particularis		Kenya	1962
Trogoderma angustum		Germany	1975
Trogoderma anthrenoides		U.S.A	1957
Trogoderma glabrum		U.S.A.	1959
Trogoderma granarium		Britain	
Trogoderma granarium		Britain	pre 1958
Trogoderma grassmani		U.S.A.	1976
Trogoderma inclusum			pre 1958
Trogoderma irroratum		Egypt	1959
Trogoderma ornatum		U.S.A.	1974
Trogoderma sternale plagifer		New Mexico	1966
Trogoderma variabile		U.S.A.	1965
Trogoderma varium		Korea	1970
Typhaea stercorea	Datchet	Britain	1980
THYSANURA			
Lepisma saccharina		Britain	1978
LEPIDOPTERA			
Ephestia cautella		Cyprus	1969
Ephestia cautella	Brown/Yellow	Florida	
Ephestia cautella	Bedstock		
Ephestia elutella	Lab.		
Ephestia elutella	Millwall	Britian	1969
Ephestia kuehniella	Welsh Buffer Depot	Britain	
Ephestia kuehniella	Rhydymwyn	Britain	1988
Ephestia kuehniella		Britain	1949
Galleria mellonella	B	U.S.A.	1992
Galleria mellonella		U.S.A.	1987
Plodia interpunctella	88	Turkey	1977
Plodia interpunctella		Britain	1968
Plodia interpunctella	121	Chicargo	1977
Plodia interpunctella	102	Tanzania	1977
Sitotroga cerealella	623	U.S.A.	1972
Sitotroga cerealella	A68	Nepal	1981
Tinea pellionella		Britain	1989
Tineola bisselliella	U.S.A. Lab. strain		
Tineola bisselliella	U.K.Wild strain		
Tineola bisselliella		Britain	1989

MUTANTS

Carpophilus dimidiatus	pearl-eye		
Cryptolestes turcicus	Red-eye mutant		
Dermestes maculatus	Black-brown	Australia	1964
Dermestes maculatus	Pearl-eye	Australia	1964
Lasioderma serricorne	Black mutant	U.S.A.	1975
Oryzaephilus mercator	0779 pearl-eye	Pacific Islands	1978
Oryzaephilus surinamensis	small	East Pakistan	1964
	484 -sp eye,lod	speckled eye, light ocular diaphragm	
	484-sp eye	speckled eye	1994
	484 black dd		
Tribolium castaneum	black		1983

SLOUGH, BUCKS, U.K.
TROPICAL DEVELOPMENT AND RESEARCH INSTITUTE (FORMERLY TPI)
STORAGE DEPARTMENT
OVERSEAS DEVELOPMENT ADMINISTRATION
PEST BIOLOGY AND INSPECTION SECTION

TROPICAL DEVELOPMENT AND RESEARCH INSTITUTE (TDRI)

The Tropical Development and Research Institute (TDRI) was formed 1 April, 1983, following the amalgamation of the Tropical Products Institute and the Centre for Overseas Pest Research. The Director of the Institute is Dr. Malcolm Thain who was formerly Director of the Tropical Products Institute.

The Institute, part of the Overseas Development Administration and funded from the aid programme, will provide technical assistance to developing countries. The budget will total over eight million pounds in the financial year 1983/84.

TDRI will continue to work on post-harvest technology and pest and vector management for the benefit of developing countries, by controlling the pests harmful to agriculture, stored products and public health, and by improved processing, storage and marketing of agricultural fisheries products.

The main emphasis of its work in scientific research and development, marketing, information, advice and training will centre on the improvement of food supplies in accordance with the major objectives of the British overseas aid programme. Work will also continue on certain non-food crops of particular importance to developing countries. These activities will be carried out, as at present, in the UK and overseas in countries throughout the developing world.

Since post harvest technology and pest and vector management are broad and varied subjects, TDRIwill concentrate its activities in those areas where it has a comparative advantage in terms of experience, knowledge and cost-effectiveness. Close cooperation will continue with government organizations, universities and industry in developing countries, the UK and other industrialized countries, and with multilateral and bilateral aid agencies.

Requests from developing country govenments qualifying for British aid will be channelled through the Overseas Development Administration, which may commission TDRI to carry out the work if it lies within the scope of its terms of reference, and if resources are available. In addition, TDRI may, subject to the claims on its resources commissioned by ODA, accept contracts for relevant work on behalf of developing countries from multilateral aid agencies and other organizations.

Stock Lists

TDRI is based in London, although relocation to a new site outside the central London area is under consideration. It currently employs over 450 staff.

Requests for information, advice, investigations or training should be sent to:

The Director
Tropical Development and Research Institute
56-62 Gray's Inn Road
London WC1X 8LU
England (Telephone 01-242 5412)

All stocks are maintained at 27 degrees centigrade and 70% R.H. The stocks listed below are those currently maintained for ongoing research projects. Other storage pest species are kept in culture from time to time for training or short research projects.

I. Wild type strains

A. Coleoptera

Bostrichidae
1. Prostephanus truncatus -- Mexico, Tanzania

Bruchidae
1. Acanthoscelides obtectus -- Swaziland; Turkey
2. Callosobruchus analis -- MAFF Lab., Slough; Indonesia
3. Callosobruchus chinensis -- Nepal; Kenya
4. Callosobruchus maculatus -- Brazil, 2 strains; Nigeria, 2 strains; Oman; Senegal; Sierra leone; Turkey; Upper Volta; Yemen.
5. Caryedon serratus -- Unknown
6. Zabrotes subfasciatus -- Uganda (collected from cowpeas and bred on cowpeas); Colombia.

Curculionidae
1. Sitophilus oryzae -- Peru (pulse-feeding strain breeding on split peas)
2. S. zeamais -- Mexico

B. Lepidoptera

Galleriinae: Corcyra cephalonica -- Malawi

Gellechiidae: Sitotroga cerealella -- Sudan

Phycitinae: Ephestia cautella -- Brazil

CHEMICAL CONTROL SECTION

(stocks of some major beetles pests are maintained, under selection pressure with insecticide where necessary, in order to enable the FAO recommended methods for the detection and measurement of resistance to be carried out. Incoming strains from abroad are screened and the methods are demonstrated in training programs.)

Wild type strains

Coleoptera

Bostrichidae

Prostephanus truncatus--Strains tested for phosphine resistance: Botswana; Indonesia; Mali (8 strains) Nepal; Nigeria; Pakistan (2 strains) Singapore; Sri Lanka (4 strains); Tunisia; Zimbabwe.

Bruchidae

Acanthoscelides obtectus -- Ethiopia

Callosobruchus chinensis -- India

Curculionidae

Sitophilus oryzae -- Insecticide-susceptible strain (reference strain) -- via MAFF Lab, Slough

S. oryzae -- Malathion and lindane resistant strain (A.76) -- via MAFF Lab., Slough.

Tenebrionidae

Tribolium castaneum -- Multiple insecticide-resistant strain (CTC 12) -- australia

T. castaneum -- Malathion-specific resistant strains (Kano C) -- Nigeria

T. castaneum -- Insecticide-susceptible strain (reference strain) -- MAFF Lab, Slough

Dr. P. F. Prevett
Deputy Head of Department

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I. Wild type strains

A. Coleoptera

Anobiidae

1. Lasioderma serricorne	a. Unknown
2. Stegobium paniceum	a. ex-MAFF

Bostrichidae

1. Dinoderus distinctus	a. Tanzania
2. D. minutus	a. Indonesia
3. D. porcellus	a. Togo
4. Prostephanus truncatus	a. Costa Rica
	b. Mexico (3 strains)
	c. Nigeria
	d. Tanzania (4 strains)
	e. Togo
	f. Kenya
5. Rhyzopertha dominica	a. Ex-MAFF
	b. Angola‡
	c. Kenya (3 strains)‡‡‡
	d. Mali ‡
	e. Morocco ‡
	f. Nepal‡
	g. Sri Lanka

Bruchidae

1. Acanthoscelides obtectus --	a. Colombia (2 strains)
	b. Uganda
	c. Zimbabwe
2. Callosobruchus analis --	a. MAFF Lab.
3. Callosobruchus chinensis --	a. Indonesia
4. Callosobruchus maculatus --	a. Uganda
5. Caryedon serratus	a. India
6. Zabrotes subfasciatus --	b. Uganda

Curculionidae	
1. *Sitophilus oryzae*	
i. Normal strains	a. Ex-MAFF
	b. India
	c. Morocco
	d. Zimbabwe
ii. Pulse-feeding	a. Burma
2. *S. zeamais* --	a. Ex-MAFF
	b. India
Dermestidae	
1. *Dermestes ater*	a. Ex-MAFF
2. *D. maculatus*	a. Jamaica
3. *Trogoderma granarium*	a. India
	b. Sudan
Histeridae	
1. *Teretriosoma nigrescens*	a. Mexico
Lophocateridae	
1. *Lophocateres pusillus*	a. Philippines
Silvanidae	
1. *Ahasverus advena*	a. Ex-MAFF
2. *Oryzaephilus sp.*	a. Kenya (4 strains)
3. *Oryzaephilus surinamensis*	a. Ex-MAFF
Tenebrionida	
1. *T. castaneum*	a. Ex-MAFF
	b. Botswana‡
	c. Indonesia (2 strains)
	d. Kenya #
	e. Mali‡
	f. Mozambique
	g. Pakistan‡
	h. Philippines +
	i. Sri Lanka
	j. Thailand (3 strains)‡‡‡+
	k. Zimbabwe (2 strains)‡
2. *Latheticus oryzae*	a. Ex-MAFF
3. *Gnatocerus cornutus*	a. Ex-MAFF
4. *Palorus subdepressus*	a. Ex-MAFF

Key

‡ Number of strains which have to date been found to be Phosphine resistant.

+ Malathion resistance noted.

Pirimiphos methyl resistance noted.

B. Lepidoptera

Pyralidae

1. Corcyra cephalonica	a. Ex-MAFF
2. Ephestia cautella	a. Ex-MAFF
	b. Ethiopia
3. Ephestia elutella	a. Ex-MAFF

Gellechiidae:

1. Sitotroga cerealella	a. Sudan

CHEMICAL CONTROL SECTION

(stocks of some major beetles pests are maintained, under selection pressure with insecticide where necessary, in order to enable the FAO recommended methods for the detection and measurement of resistance to be carried out. Incoming strains from abroad are screened and the methods are demonstrated in training programs.)

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T. castaneum -- Insecticide-susceptible strain (reference strain) -- MAFF Lab, Slough

Dr. Chris P. Haines

YUGOSLAVIA

INSTITUTE FOR BIOLOGICAL RESEARCH
"SINIŠA STANKOVIĆ"
UNIVERSITY OF BELGRADE
DEPARTMENT OF INSECT PHYSIOLOGY & BIOCHEMISTRY

1. *Morimus funereus*, L. (Cerambycidae - Coleoptera), wild type, Fruška Gora & Derdap, Serbia (geographic origin)

2. *Cerambyx cerdo*, L. (Cerambycidae - Coleoptera), wild type, Fruška Gora, Serbia

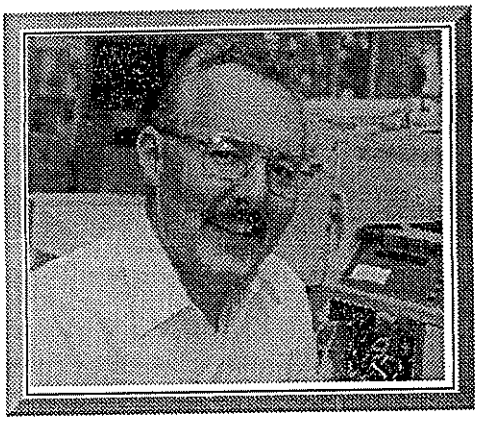
3. *Tenebrio molitor*, L. (Tenebrionidae - Coleoptera), wild type, Fruška Gora, Serbia

4. *Lymantria dispar*, L. (Lymantriidae - Lepidoptera), wild type, Despotovac, Serbia

Dr. Zlatko Prolic, Ph. D.

THE USDA-ARS GRAIN MARKETING AND PRODUCTION RESEARCH CENTER, MANHATTAN, KANSAS

THE USDA-ARS GRAIN MARKETING AND P.R.C., MANHATTAN, KANSAS



Dr. Karl Kramer (Acting Research Leader)

Biological Research Unit ;
Grain Marketing and Production Research Center

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The mission of the Unit is to develop economically- and ecologically- sound methods to manage insect pests in stored grain, processed commodities, and storage and processing facilities. A multidisciplinary team conducts fundamental and applied research on new biological and ecological approaches to pest management that will reduce the use of traditional pesticides on grain and grain products. Successful completion of the mission will provide a sustainable supply of high-quality cereal products.

We conduct research on biological control agents, insect-resistant packaging, novel physiological control techniques, host plant resistance, insecticide deployment and resistance management strategies, insect biochemistry and genetics, insect population monitoring, population dynamics and behavior, and computer-based integrated pest management systems.

♦BRU

Last Edited: July 8, 1997
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USDA U.S. Department of Agriculture
ars Agricultural Research Service

GMPRC
GRAIN MARKETING AND PRODUCTION RESEARCH CENTER

Biological Research Unit: Scientists

Dr. Frank Arthur
Integrated Pest Management Technologies, Insecticides in Food Processing

Dr. James E. Baker
Parasitoid Biology and Toxicology, Digestive Physiology

Dr. Richard Beeman
Insect Molecular Genetics, Insecticide Resistance

Dr. Charles Burks
Low Temperature Biology

Dr. Alan Dowdy
Insect Ecology and Molecular Biology

Dr. Paul Flinn
Insect Modeling, Expert Systems, Biological Control

Dr. David Hagstrum
Insect Ecology, Modeling, Sampling, Acoustic Detection

Dr. Ralph Howard
Chemical Ecology, Biological Control, Insect Hormone Physiology

Dr. Donovan Johnson
Microbiology of Insect Pathogens

Dr. Karl Kramer
Insect Biochemistry and Physiology, Biopesticides,

Dr. William H. McGaughey
Microbial Insecticides, Integrated Pest Management

Dr. Michael Mullen
Insect Trapping, Insect Resistant Packaging

Dr. Brenda Oppert
Insect Physiology/ Toxicology

Dr. James Throne
Ecology, Modeling, Seed Resistance to Insects

Dr. Yu-Cheng Zhu
Molecular Biology

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Research Interests

Frank Arthur received his Ph.D. In Entomology from North Carolina State University in December 1985. He joined the staff of the Stored Product Insects Research and Development Laboratory at Savannah, GA in March 1986, and was transferred to the Grain Marketing and Production Research Center upon closure of the Savannah Laboratory in November 1994. He is responsible for developing applied research programs for insect pest management in stored cereal grains and processed food warehouses. Previous studies have included pesticide degradation on stored commodities, residual efficacy of insecticides applied to different substrates, evaluation of new chemicals for use in post-harvest environments, and expanded use of aeration to control insect pests in stored grains. Current research interests are the development of aeration management strategies for crops stored in different geographic regions, evaluation of microbial pathogens for use in raw grains or on surface substrates, identification of physical and environmental factors that affect the efficacy of residual insecticides, and simulated field studies involving chemical and non-chemical controls. Research projects often involve cooperative efforts with private industry, other entomologists at the Manhattan laboratory, research and extension entomologists at various state universities, and biologists associated with the U. S. Military.

Project Information

Pyrethrin aerosol field demonstration trial

Recent Publications

Arthur, F. H. 1996. Grain protectants: current status and prospects for the future. J. stored Prod. Res. 32(4): 293-302.

Arthur, F. H. and H. L. Johnson. 1995. Development of aeration plans based on weather data: a model for management of corn stored in Georgia. Am. Entomol. 41: 241-246.

Arthur, F. H. 1995. Aeration alone versus Chlorpyrifos-Methyl treatment followed by aeration for wheat stored in Georgia: simulated field test. J. Econ. Entomol. 88(6): 1764-1770.

Arthur, F. H. 1997. Differential effectiveness of deltamethrin dust on wood, concrete, and tile surfaces against three stored-product beetles. J. stored Prod. Res. (In Press).

Click here to see more publications.

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Dr. James E. Baker

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Grain Marketing and Production Research Center

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Recent Publications

BAKER, J. E., PEREZ-MENDOZA, J., and BEEMAN, R. W. Inheritance of malathion resistance in the parasitoid, *Anisopteromalus calandrae* (Hymenoptera: Pteromalidae). J. Econ. Entomol. (In press)

REECK, G. R., KRAMER, K. J., BAKER, J. E., KANOST,M., FABRICK, J. A., and BEHNKE, C. Proteinase inhibitors and resistance of transgenic plants to insects. *In* Transgenic Plants for Control of Insect Pests. N. Carozzi and M. Koziel, [eds.], Taylor and Francis Publ., Washington, D. C. (In Press)

WEAVER, D. K., ZETTLER, J. L., WELLS, C. D., BAKER, J. E., BERTSCH, W., and THRONE, J. E. Toxicity of fractionated and degraded mexican marigold floral extract to adult, *Sitophilus zeamais* (Coleoptera: Curculionidae). J. Econ. Entomol. (In press)

BAKER, J. E. and KRAMER., K. J. 1996. Biotechnological approaches for stored-product insect pest control. Postharvest News and Information 7: 11N-18N.

TERRA, W. R., FERREIRA, C., and BAKER, J. E. 1996. Compartmentalization of digestion. *In* Biology of the Insect Midgut, M. J. Lehane and P. F. Billingsley, [eds.], Chapman & Hall, New York, pp 206-235.

Baker, J.E., and J.E. Throne. 1995. Evaluation of a resistant parasitoid for biological control of weevils in insecticide-treated wheat. Journal of Economic Entomology 88: 1570-1579.

Baker, J.E., Weaver, D.R., Throne, J.E. and Zettler, J.L. 1995. Resistance to protectant insecticides in two field strains of the stored-product insect parasitoid *Bracon hebetor* (Hymenoptera: Braconidae). J. Econ. Entomol. 88: 512-519.

Throne, J.E., J.E. Baker, and G.E. Scott. 1995. Development of maize weevils (Coleoptera: Curculionidae) on corn lines resistant to an aflatoxin-producing fungus. Environmental Entomology 24: 944-949.

Throne, J.E., Weaver, D.K., & Baker, J.E. 1995. Probit analysis: Assessing goodness-of-fit based on backtransformation and residuals. J. Econ. Entomol. 88(5): 1513-1516.

Throne, J.E., Weaver, D.K., Chew, V., & Baker, J.E. 1995. Probit analysis of correlated data: Multiple observations over time at one concentration. J. Econ. Entomol. 88(5):1510-1512.

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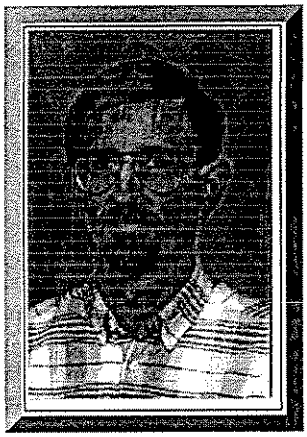
THE USDA-ARS GRAIN MARKETING AND P.R.C., MANHATTAN, KANSAS



Dr. Richard Beeman

Biological Research Unit ;
Grain Marketing and Production Research Center

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Email: beeman@usgmrl.ksu.edu

Research Interests

My research emphasis is on the genetics and molecular biology of insect pests of stored products.

I am currently involved in efforts to characterize genes that regulate resistance to insecticides and pathogens, develop DNA vectors for genetic engineering of pest and beneficial insects, discover and evaluate parasitic and lethal genes that occur naturally in pest insect populations, and develop molecular markers for population monitoring and resistance diagnosis.

Project Information

Insect Molecular Genetics

Selected Publications

BAKER, J. E., PEREZ-MENDOZA, J., and BEEMAN, R. W. Inheritance of malathion resistance in the parasitoid, *Anisopteromalus calandrae* (Hymenoptera: Pteromalidae). J. Econ. Entomol. (In press)

BEEMAN, R. W. and STAUTH, D. M. Rapid cloning of insect transposon insertion junctions using "universal" PCR. Insect. Molec. Biol. (In press)

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BEEMAN, R. W., THOMSON, M. S., CLARK, J. M., DE CAMILLIS, M. A., BROWN, S. J., and DENELL, R. E. 1996. Woot, an Active gypsy-class retrotransposon in the flour beetle *Tribolium castaneum*, is associated with a recent mutation. Genetics 143: 417-426.

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THE USDA-ARS GRAIN MARKETING AND P.R.C., MANHATTAN, KANSAS

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Research Interests

I am a research entomologist with the USDA-ARS at the U.S. Grain Marketing Research and Production Center in Manhattan, Kansas. I received my Ph.D. in entomology from the University of Missouri-Columbia in 1991, and have since done postdoctoral work at the University of Notre Dame and at Miami University of Ohio. My research interests revolve around fundamental and applied aspects of the physiological ecology of overwintering in arthropods. Further information on these topics my be found on my KSU home page.

Current Research Projects

- Comparative studies of cold hardiness and capacity for acclimation in coleopteran pests of stored grain
- Cold hardiness and overwintering capabilities of hymenopteran parasitoids of stored grain pests
- Development of *Musca* spp. as a model system for mechanisms of chilling injury and cold hardening

Recent Publications

H. L. Troyer, C. S. Burks, and R. E. Lee. 1996. Phenology of cold hardiness in reproductive and migrant monarch butterflies (*Danaus plexippus*) in southwest Ohio. Insect Physiology 42:663-672

Burks, C. S., R. J. Stewart, G. Needham, and R. E. Lee. 1996. The role of direct chilling injury and inoculative freezing in cold tolerance of *Amblyomma americanum*, *Dermacentor variabilis* and *Ixodes scapularis*. Physiological Entomology 21:44-50.

Burks, C. S., R. J. Stewart, G. Needham, and R. E. Lee. 1995. Cold hardiness characteristics of ixodid ticks. Proceedings of the Ninth International Congress of Acarology [accepted for publication].

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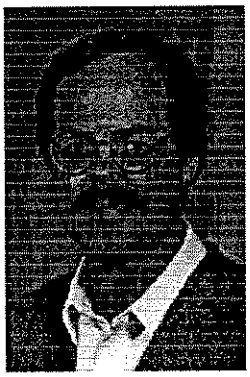

Alan K. Dowdy, Ph.D.

Research Entomologist
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CRIS # 5430-43000-017. Monitoring & Control Strategies for Stored-Product Insects.

Research Focus

This project focuses on the behavior and ecology of stored-product insects in and around commerical grain storage, processing facilities and retail outlets. These studies will determine where pest insects come from to infest commercial facilities and will emphasize the importance of refugial populations in and around these facilities and the movement of infested commodities through the market channels. Additionally, the effectiveness of selected control approaches will be assessed for integration into ecologically-compatible pest management systems.

Current Research Projects

- Precision targeting of stored-product insect populations in commercial grain storage facilities
- Monitoring and movement of stored-product insects in and around commercial storage facilities
- Heat susceptibility of confused and red flour beetles as influenced by insect age and sex
- Evaluation of heat sterilization of processing plants for insect control.
- Isolation and sequencing of trypsin and chymotrypsin genes from Indianmeal moth

Recent Publications

- Dowdy, A. K., and W. H. McGaughey. 1992. Fluorescent pigments for marking lesser grain borers. *Journal of Economic Entomology* 85: 567-569.
- Dowdy, A. K., R. W. Howard, L. Seitz, and W. H. McGaughey. 1993. Response of *Rhyzopertha dominica* (Coleoptera: Bostrichidae) to its aggregation pheromone and wheat volatiles. *Environmental Entomology* 22: 965-970.
- Dowdy, A. K., and W. H. McGaughey. 1994. Seasonal activity of stored-product insects in and around farm-stored wheat. *Journal of Economic Entomology* 87: 1351-1358.
- Dowdy, A. K. 1994. Flight initiation of *Rhyzopertha dominica* (Coleoptera: Bostrichidae) as influenced by temperature, humidity, and light. *Journal of Economic Entomology* 87: 1714-1717.
- Hagstrum, D. W., A. K. Dowdy and G. E. Lippert. 1994. Early detection of insects in stored wheat using sticky traps in bin headspace and prediction of infestation level. *Environmental Entomology* 23: 1241-1244.
- Dowdy, A. K. and W. S. Fargo. 1995. Population dynamics and sampling: insect migration. *In* G. W. Cuperus [ed.], *Proceedings of the Fourth National Stored Grain Pest Management Conference*. OSU Circular E-946, pp 119-126.

- Dowdy, A. K., and W. H. McGaughey. 1996. Using random amplified polymorphic DNA to differentiate strains of the Indianmeal moth (Lepidoptera: Pyralidae). *Environmental Entomology* 25: 396-400.
- Fields, P., A. Dowdy, and M. Marcotte. 1997. Structural Pest Control: The use of an enhanced diatomaceous earth product combined with heat treatment for the control of insect pests in food processing plants. *Canada - United States Working Group on Methyl Bromide Alternatives.*
- Dowdy, A. K., and M. A. Mullen. Multiple Stored-Product Insect Pheromone Use in Pitfall Traps. *Journal of Stored Products Research* (in press).

Biographical Information

Education

- Ph.D. in Entomology (Crop Protection), Oklahoma State University, Stillwater (1988)
- M.S. in Entomology, Oklahoma State University, Stillwater (1985)
- B.S. in entomology, University of Wyoming, Laramie (1982)
- A.A.S. in Business Administration, Laramie County Community College, Cheyenne, Wyoming (1980)

Employment

- Research Entomologist, USDA, ARS, Grain Marketing & Production Research Center, Manhattan, Kansas (1992 - present)
- Research Associate, USDA, ARS, US Grain Marketing Research Laboratory, Manhattan, Kansas (1989-1992)
- Analytical Entomologist, US Food & Drug Administration, New York Regional Laboratory, Brooklyn (1988-1989)

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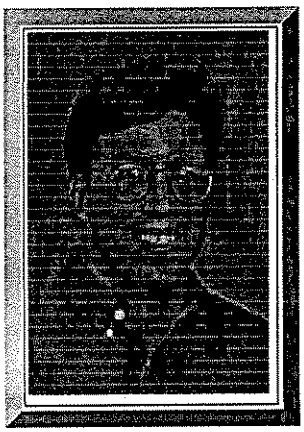

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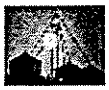
Research Interests

Paul W. Flinn is a research biologist with the USDA-ARS at the U.S. Grain Marketing Research Laboratory in Manhattan, Kansas. Flinn received his Ph.D. in Entomology from PennState University in 1984. His interests center on the development and analysis of IPM systems through computer simulation of crop-pest agroecosystems and knowledge-based systems. His current research involves developing computer models that predict the spatial population dynamics of stored-grain insect pests, and on models that predict the population dynamics of parasitic wasps that attack grain beetles. Flinn is responsible for the development of Stored Grain Advisor (SGA), an expert system for stored grain management. Over 1000 copies of this software are currently being used in the U.S.

Project Information

Biological Control Expert Systems Insect Modeling



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Recent Publications

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D.W. Hagstrum [eds.], Integrated Management of Insects in Stored Products. Marcel Dekker, Inc., N.Y.

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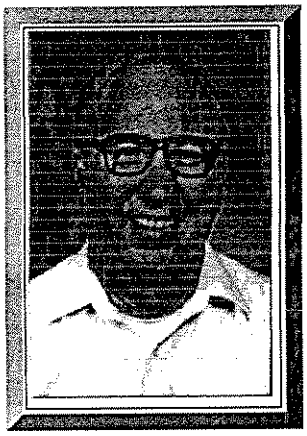

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Recent Publications

FLINN, P. W. and HAGSTRUM, D. W. Simulation model of low oxygen atmospheres on insect population dynamics in stored grain. Proc. Internat. Controlled Environ. Workshop. (In press)

FLINN, P. W., HAGSTRUM, D. W., and MUIR, W. E. The effects of time of aeration, bin size, and latitude on insect populations in stored wheat: a simulation study. J. Econ. Entomol.(In press)

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SUBRAMANYAM, BH., HAGSTRUM, D. W., MEAGHER, R. L., BURKNESS, E.C., HUTCHISON, W. D., and NARANJO, S. E. Developmentand evaluation of sequential sampling plans for *Cryptolestes ferrugineus* (Stephens) (Coleoptera: Cucujidae) infesting farm-stored wheat. J. Stored Prod. Res. (In Press)

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Aslam, M., Hagstrum, D.W. and Dover, B.A. 1994. The effect of photoperiod on the flight activity and biology of *Rhyzopertha dominica* . J. KS Entomol. Soc. 67:107-115.

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Last Edited: April 8, 1996
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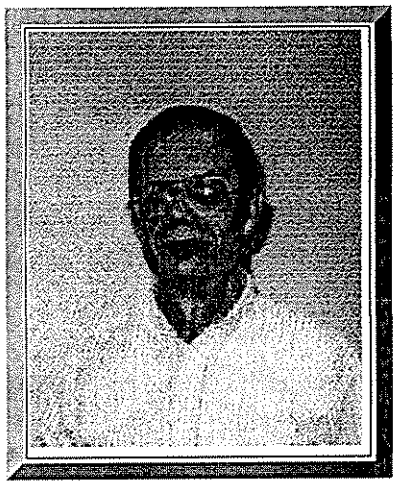
THE USDA-ARS GRAIN MARKETING AND P.R.C., MANHATTAN, KANSAS



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Research Interests

Chemical and physiological ecology, especially the roles of cuticular hydrocarbons and other semiochemicals in structuring arthropod communities; Chemical systematics using cuticular hydrocarbons as characters; Behavioral ecology of stored product parasitoids and their hosts; Development of biocontrol strategies for stored grain insect pests; Insect biochemistry and endocrinology, especially the roles of eicosanoids in insect immune responses, ion- and water-regulation and thermoregulation.

Recent Publications

HOWARD, R. W. and INFANTE, F. 1996. Cuticular hydrocarbonsof the host-specific ectoparasitoid, *Cephalonomia stephanoderis* (Hymenoptera:Bethylidae) and its host the coffee berry borer (Coleoptera:Scolytidae). Annals Entomol. Soc. Am. 89: 700-709.

HOWARD, R. W. and STANLEY-SAMUELSON, D. W. 1996. Fatty acid composition of fat body and malpighian tubules of the tenebrionid beetle, *Zophobas atratus:* significance in eicosanoid-mediated physiology. Comp. Biochem. Physiol. Vol. 115B: 429-437.

HOWARD, R. W. and STANLEY-SAMUELSON, D. W. 1996. Eicosanoids as mediators of critical physiological functions in insects. *In* Proc. XXth Int. Congress Entomol., Florence,Italy, p. 567 [abstract].

JOHNSON, D. E. and HOWARD, R. W. 1996. Inhibitors of eicosanoid biosynthesis and their effect upon *Bacillus thuringiensis*delta-endotoxin response in cultured insect cells and developing larvae. Curr. Microbiol. 32: 1-6.

MILLER, J. S., HOWARD, R. W., NGUYEN, T., NGUYEN,A., ROSARIO, R. M. T., and STANLEY-SAMUELSON, D. W. 1996. Eicosanoids mediate nodulation responses to bacterial infections in larvae of the tenebrionid beetle, *Zophobas atratus*. J. InsectPhysiol., 42: 3-12.

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Howard, R.W. & Akre, R.D. 1995. Propaganda, Crypsis, and Slave-making. Chapter 10, In Chemical Ecology of Insects 2, [R.T. Carde and W.J. Bell, eds.l. Chapman & Hall, Publishers. pp 364-424.

Howard, R.W., Howard, C.D., & Colquhoun, S. 1995. Ontogenetic and environmentally induced changes in cuticular hydrocarbons of *Oryzaephilus surinamensis* (Coleoptera: Cucujidae). Ann. Entomol. Soc. Am. 88:485-495.

Howard, R.W. and Schaeffer, C.W. 1994. Ideas: The raison d'etre of a scientific article. Am. Entomol. 40:16-17.

Toolson, E.C., Ashby, P.D., Howard, R.W. and Stanley-Samuelson, D.W. 1994. Eicosanoids mediate control of thermoregulatory sweating in the cicada *Tibicen dealbatus* (Insecta: Homoptera). J. Comp. Physio. 164:278-285.

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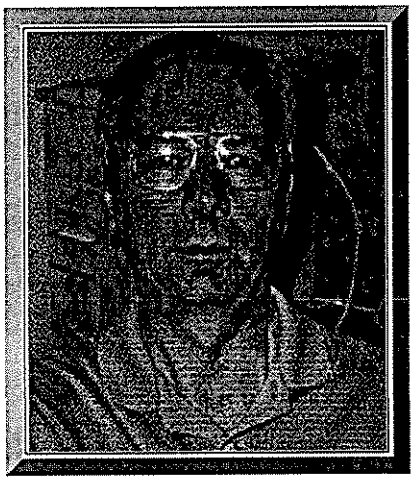

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Research Interests

Don is a research microbiologist with the USDA-ARS at the U.S. Grain Marketing Research Laboratory in Manhattan, Kansas. He has been with the Agricultural Research Service for over 29 years, having started with the Northern Regional Research Laboratory in Peoria, Illinois shortly after received his M.S. from the University of Nebraska in 1966. He earned his Ph.D. from the University of Wisconsin while on leave from government service from 1969 to 1972. Upon returning to Peoria, he worked on various projects, including control of the Japanese beetle with *Bacillus japonica*. In 1981, he transferred to the Grain Marketing Research Laboratory to work on the control of stored product Lepidoptera with *Bacillus thuringiensis*. He specializes in the microbiology and biochemistry of insect pathogens, especially *Bacillus thuringiensis*. He is interested in the mode of action of *B. thuringiensis* toxins, the ability of insects to become resistant to *B. thuringiensis*, and insect tissue culture.

Current Research Projects

*** Characterize resistance in the Indianmeal moth to *B. thuringiensis*. Includes a number of studies involving midgut membrane binding of sensitive and resistant larvae to different Cry proteins, larval midgut protease activation of protoxin, and relative fitness costs due to the acquisition of resistance (Cooperators: Dr. W. H. McGaughey, Dr. B. Oppert, Dr. Karl Kramer, Dr. A. Aronson).

*** Investigate synergistic relationship between spores and crystals of *B. thuringiensis*, which affects toxicity levels of spore-crystal mixtures when compared with pure crystal preparations and cloned crystal protein. (Cooperator: Dr. W. H. McGaughey).

Selected Publications

JOHNSON, D. E. and HOWARD, R. W. 1996. Inhibitors of eicosanoid biosynthesis and their effect upon *Bacillus thuringiensis* delta-endotoxin response in cultured insect cells and developing larvae. Curr. Microbiol. 32: 1-6.

JOHNSON, D. E. and MCGAUGHEY, W. H. 1996. Contribution of *Bacillus thuringiensis* spores to toxicity of purified Cry proteins towards Indianmeal moth larvae. Curr. Microbiol.33: 54-59.

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MOHAMMED, S. I., JOHNSON, D. E., and ARONSON, A.I. 1996. Altered binding of the Cry1Ac toxin to larval membranes but not to the toxin-binding protein in *Plodia interpunctella* selected for resistance to different *Bacillus thuringiensis* isolates. Appl. Environ. Microbiol. 62: 4168-4173.

OPPERT, B. S. , KRAMER, K. J., JOHNSON, D. E., UPTON, S. J., and MCGAUGHEY, W. H. 1996. Luminal proteinases from *Plodia interpunctella* and the hydrolysis of *Bacillus thuringiensis* CryIA(c) protoxin. Insect Biochem. Molec. Biol. 26:571-583.

Johnson, D. E. 1994. Cellular toxicities and membrane binding characteristics of insecticidal crystal proteins from *Bacillus thuringiensis* toward cultured insect cells. J. Invertebr. Pathol. 63:123-129.

McGaughey, W. H., and Johnson, D. E. 1994. Influence of crystal protein composition of *Bacillus thuringiensis* strains on cross resistance in Indianmeal moths (Lepidoptera: Pyralidae). J. Econ. Entomol. 87:535-540.

Oppert, B., Kramer, K. J., Johnson, D. E., MacIntosh, S. C., and McGaughey, W. H. 1994. Altered protoxin activation by midgut enzymes from a *Bacillus thuringiensis* resistant strain of *Plodia interpunctella*. Biochem. Biophy. Res. Comm. 198:940-947.

McGaughey, W. H., and Johnson, D. E. 1992. Indianmeal moth (Lepidoptera: Pyralidae) resistance to different strains and mixtures of *Bacillus thuringiensis*. J. Econ. Entomol. 85:1594-1600.

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Van Rie, J., McGaughey, W. H., Johnson, D. E., Barnett, B. D., and Van Mellaert, H. 1990. Mechanism of insect resistance to the microbial insecticide *Bacillus thuringiensis*. Science 247:72-74.

Johnson, D. E., Brookhart, G, L., Kramer, K. J., Barnett, B. D., and McGaughey, W. H. 1990. Resistance to *Bacillus thuringiensis* by the Indianmeal moth, *Plodia interpunctella*: Comparison of midgut proteinases from susceptible and resistant larvae. J. Invertebr. Pathol. 55:235-244.

McGaughey, Wm. H., and Johnson, D. E. 1987. Toxicity of different serotypes and toxins of *Bacillus thuringiensis* to resistant and susceptible Indianmeal moths (Lepidoptera: Pyralidae). J. Econ. Entomol. 80:1122-1126.

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THE USDA-ARS GRAIN MARKETING AND P.R.C., MANHATTAN, KANSAS

Dr. Karl Kramer (Acting Research Leader and Research Chemist)

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Research Interests

Dr. Kramer is a biochemist internationally recognized for a comprehensive research program investigating insect cuticle structure and metabolism, molting and digestive enzymes, and the use of insect growth regulators and biopesticides for insect pest control. Results of his research have far-reaching implications in preharvest and postharvest insect pest management programs including the development of transgenic plants and biological control agents by the agricultural biotechnology industry. He is a research chemist at the ARS-USDA Grain Marketing and Production Center in Manhattan, Kansas.

The Insect Biochemistry and Physiology Laboratory at the USGMRL is dedicated to developing a greater base of information about insect metabolic and physiological processes, and using this knowledge to facilitate the development of new approaches to stored product insect pest population management. We are studying unique aspects of insect biochemistry and physiology with an emphasis on insect-specific metabolism associated with gut and cuticle physiology, and are developing insect growth regulators, biological control agents, and pest-resistant varieties of cereals for controlling insects and fungi that are responsible for destruction, contamination, and spoilage of stored grain and processed commodities.

Specific research projects include:

1. Characterization of novel biopesticides and insect growth regulating factors for stored product insect pest control.
2. Manipulation of insect chitinolytic enzymes and their genes for insect pest control.
3. Characterization of catecholamine metabolism for insect cuticle tanning and insect pest control.

We have identified proteinaceous factors that are disruptive to insect digestion, molting, and nutrition and which have the potential for genetic manipulation. Insect digestive and molting enzymes have been characterized, and inhibitory and antinutritional proteins have been found to exhibit insecticidal and growth inhibiting effects in bioassays. Examples of experimental insect control proteins include two vitamin binding proteins, several insect digestive enzyme inhibitors from wheat, rice, corn, and barley, and an enzyme that destroys the insect's exoskeleton and gut lining. The genes for these biologically active proteins have been cloned and transferred to plants and insect pathogens, which are being evaluated for host plant resistance and biological control efficacy. These studies are conducted in collaboration with Drs. Subbaratnam Muthukrishnan and Gerald Reeck, Department of Biochemistry.

We are also characterizing reactants, intermediates, products, and enzymes responsible for cuticle tanning, which might be disrupted by novel insect-selective control agents. We characterized several new catecholamine metabolites, structural proteins and carbohydrates, and oxidative enzymes that

participate in cuticle cross-linking reactions, and conducted solid-state NMR analysis of intact cuticles to determine the compositional changes and molecular interactions that occur during cuticle stabilization. These studies are conducted in collaboration with Drs. Theodore Hopkins (Entomology), Dale Hawley (Chemistry), Delbert Mueller (Biochemistry), Jacob Schaefer (Chemistry, Washington University, St. Louis) and Kenneth Tomer (National Institute of Environ mental Health).

Recent Publications

CHOI, H. K., CHOI, K. H., KRAMER, K. J., and MUTHUKRISHNAN, S. Isolation and characterization of a genomic clone for the gene of an insect molting enzyme, chitinase. Insect Biochem.Molec. Biol. (In press)

KRAMER, K. J., MUTHUKRISHNAN, S., JOHNSON, L., and WHITE, F. Chitinases for insect control. *In* Transgenic Plants for Control of Insect Pests, N. Carozzi and M. Koziel, [eds.], Taylor and Francis Publ., Washington, D. C. (In Press)

OPPERT, B. S., KRAMER, K. J., and MCGAUGHEY, W.H. Rapid microplate assay of complex proteinase mixtures. BioTechniques (In press)

REECK, G. R., KRAMER, K. J., BAKER, J. E., KANOST,M., FABRICK, J. A., and BEHNKE, C. Proteinase inhibitors and resistance of transgenic plants to insects. *In* Transgenic Plants for Control of Insect Pests. N. Carozzi and M. Koziel, [eds.], Taylor and Francis Publ., Washington, D. C. (In Press)

WANG, X., DING, X., GOPALAKRISHNAN, B., MORGAN, T.D., JOHNSON, L., WHITE F., MUTHUKRISHNAN, S., and KRAMER, K..J. Characterization of a 46 kDa insect chitinase from transgenic tobacco. Insect Biochem. Molec. Biol. (In press)

XU, R., HUANG, X., HOPKINS, T. L., and KRAMER, K.J. Catecholamine and histidyl protein cross linked structures in sclerotized insect cuticle. Insect Biochem. Molec. Biol. (In press)

AHMAD, S. A., HOPKINS, T. L., and KRAMER, K. J. 1996. Tyrosine b-glucosyltransferase in the tobacco hornworm, *Manduca sexta* (L.): properties, tissue localization, and developmental profile. Insect Biochem. Molec. Biol. 26: 49-57.

BAKER, J. E. and KRAMER., K. J. 1996. Biotechnological approaches for stored-product insect pest control. Postharvest News and Information 7: 11N-18N.

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MERRITT, M. E., CHRISTENSEN, A. M., KRAMER, K. J.,HOPKINS, T. L., and SCHAEFER, J. 1996. Detection of inter-catechol-proteincross-links in insect cuticle by carbon-13 and nitrogen-15 NMR. J. Amer. Chem. Soc. 118:11278-11282.

OKOT-KOTBER, B. M., MORGAN, T. D., HOPKINS, T. L., and KRAMER, K. J. 1996. Catecholamine containing proteins from the pharate pupal cuticle of the tobacco hornworm, *Manduca sexta*. Insect Biochem. Molec. Biol. 26: 475-484.

OPPERT, B. S. , KRAMER, K. J., JOHNSON, D. E., UPTON, S. J., and MCGAUGHEY, W. H. 1996. Luminal proteinases from *Plodia interpunctella* and the hydrolysis of *Bacillus thuringiensis* CryIA(c) protoxin. Insect Biochem. Molec. Biol. 26:571-583.

UJVARY, I., MATOLSY, G., BELAI, I., SZURDOLSI, F., BAUER K., VARJAS, L., and KRAMER, K. J. 1996. Projuvenoids:synthesis and biological evaluation of sulfenylated, sulfinylated, and sulfonylated carbamates. Arch. Insect Biochem. Physiol. 32:659-669.

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Gopalakrishnan, B., Muthukrishnan, S. and Kramer, K. J. 1995. Baculovirus mediated expression of a *Manduca sexta* chitinase gene: properties of the recombinant protein. Insect Biochem. Molec. Biol. 25, 255-265.

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Kramer, K. J., Hopkins, T. L. and Schaefer, J. 1995. Applications of solids NMR to the analysis of insect sclerotized structures. Insect Biochem. Molec. Biol. 25, 1067-1080.

Pueyo, J. J., Morgan, T. D., Ameenuddin, N., Liang, C., Reeck, G. R., Chrispeels, M. J. and Kramer, K. J. 1995. Effects of red kidney bean (*Phaseolus vulgaris*) and hard red winter wheat (*Triticum aestivum*) alpha-amylase inhibitors on alpha-amylase activity and growth of stored product insects. Entomol. exper. appl. 75, 237-244.

Wappner, P., Kramer, K. J., Hopkins, T. L., Merritt, M., Schaefer, J. and Quesada-Allue, L. A. 1995. White pupa: a *Ceratitis capitata* mutant lacking catecholamines for tanning the puparium. Insect Biochem. Molec. Biol. 25, 365-373.

Xu, R., Huang, X., Kramer, K. J. and Hawley, M. D. 1995. On-column reduction of catecholamine quinones in stainless steel columns during liquid chromatography. Analyt. Biochem. 231, 72-81.

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Morgan, T. D., Oppert, B., Czapla, T. H. and Kramer, K. J. 1993. Avidin and streptavidin as insecticidal and growth inhibiting dietary proteins. Entomol. exper. appli. 69, 97-108.

Mueller, D. D., Morgan, T. D., Wassenberg, J. D., Hopkins, T. L. and Kramer, K. J. 1993. 1H-and 13C-NMR of 3-O- and 4-O-conjugates of dopamine and other catecholamines. Bioconjugate Chem. 4, 47-53.

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Research Interests

Research interests since joining the USDA in 1970 include development of resistance to the sweetpotato weevil, *Cylas formicarius*, in commercial sweet potatoes and insect ecology. Current research involves the development of pheromone baited traps and trapping systems for stored-product insects. He developed and holds the patent on the FLIT-TRAK M2 a pitfall trap for several species of stored-product Coleoptera. Since 1989 he has been conducting research on insect resistant packaging. He serves as an advisor to the Armed Forces Pest Management Board for stored-product entomology. He has cooperated with the military to develop more environmentally friendly overwraps for the rations Meals-Ready-To-Eat (MRE).

Project Information

The development of insect resistant packaging involves cooperation with a number of major food processing companies. The development of insect resistant packages using no pesticides for dry pet foods, raisins, baby cereal, pancake mix, and breakfast cereals for both domestic consumption and export has been the focus of this research. Because insects use odors to detect packaged materials a cooperative project was established to develop an odor neutralizer to be incorporated into packaging materials. This material will prevent the odors from escaping and will result in the production of a package a stealth package that will be invisible to insects.

Other projects include the development of a protocol for the use of pheromone traps in commercial food processors, warehouses and grocery stores. This research is in cooperation with Dr. Alan Dowdy (a full description can be found on Dr. Dowdy's page) and will use the use precision targeting to increase the usefulness of the monitoring systems to determine pest distribution and result in reduced pesticide use in these facilities.

Research Projects

Insect Resistant Packaging

Recent Publications

DOWDY, A. K. and MULLEN, M. A. Multiple stored-product insect pheromone use in pitfall traps. J.

Stored Prod. Res. (In press)

MULLEN, M. A. Pest proof packaging to control and minimize pest populations. *In* Proc. 1996 Food Proc. Pest Manag. Workshop, Stillwater, OK. (In press)

Mullen, M.A. 1994. Rapid determination of the effectiveness of insect resistant packaging. J. Stored Prod. Res. 30:95-97.

Mullen, M.A. 1994. Response of *Cadra cautella* and *Plodia interpunctella* (Lepidoptera: Pyralidae) to pheromone baited traps. J. Entomol. Sci. 29:215-221.

Mullen, M.A. 1994. Development of pheromone baited insect traps. *In* Proc. 6th Internat. Conf. Stored-Prod. Prot., Canberra, Australia, pp. 421-424.

Mullen, M.A. 1994. Effect of single and multiple species release on the capture of *P. interpunctella* and *C. cautella* in pheromone baited traps. *In* Proc. 6th Internat. Conf. Stored-Prod. Prot., Canberra, Australia, pp. 425-429.

Wileyto, E.P., Ewens, W.J., and Mullen, M.A. 1994. Markov-recapture population estimates: a tool for improving interpretation of trapping experiments. Ecology 75, 1109-1117.

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Upcoming Meetings

Research Interests

Dr. Brenda Oppert is a Research Chemist working with Dr. Karl Kramer at the Grain Marketing and Production Research Center. Dr. Oppert received B.S. and M.S. degrees in biology from the University of Texas at El Paso. She received a Ph.D. in the area of protein biochemistry from Kansas State University in 1991. Since that time, Dr. Oppert has worked at GMPRC in the area of insect gut biochemistry.

Current Research Projects

Current research efforts are focused on insect adaptation to microbial toxins. Gut proteinases from a major stored product pest, the Indianmeal moth, have been characterized from strains that are susceptible and resistant to the insecticidal toxins from *Bacillus thuringiensis* (*Bt*). Some *Bt*-resistant strains have lower proteinase activities than other resistant and susceptible strains. Since *Bt* toxins must be activated by gut proteinases in order to be toxic to insects, this may provide an explanation for their adaptation to some *Bt* toxins. Understanding this resistance mechanism will lead to more effective control strategies using *Bt* toxins. In addition, characterization of digestive proteinases will allow for development of specific inhibitors that may also be utilized as biological control agents. Control of these pests will be an important component in minimizing insect infestations in stored products, leading to increased food supplies and enhanced productivity for farmers and producers.

Upcoming Meetings

- Dr. Oppert will be an invited speaker at the Society for Invertebrate Pathology, Banff, Canada (August, 1997). *Abstract*
- The American Institute of Chemists, Las Vegas, NV (September, 1997).
- American Chemical Society, 32nd Midwest Regional Meeting, Lake of the Ozarks, MO (October, 1997). *Abstract*
- Entomological Society of America, Nashville, TN (December, 1997).

Selected Publications

Oppert, B. Kramer, K. J., Beeman, R. W., Johnson, D. and McGaughey, W. H. 1997. Proteinase-mediated resistance to *Bacillus thuringiensis* insecticidal toxins. J. Biol. Chem. (In Press).

Oppert, B., Kramer, K. J. and Mcgaughey, W. H. 1997. Insect resistance to *Bacillus thuringiensis* toxins. The Chemist 74:7-10.

Oppert, B., Kramer, K. J., and Mcgaughey, W. H. 1997. Rapid microplate assay of complex proteinase mixtures. BioTechniques 23:70-72

Oppert, B., Kramer, K. J., Johnson, D. E., Upton, S. J., and Mcgaughey, W. H. 1996. Luminal proteinases from *Plodia interpunctella* and the hydrolysis of *Bacillus thuringiensis* CryIA(c) protoxin. Insect Biochem. Molec. Biol. 26:571-583.

Oppert, B., Kramer, K.J., Johnson, D.E., MacIntosh, S.C. and McGaughey, W.H. 1994. Altered protoxin activation by midgut enzymes from a *Bacillus thuringiensis* -resistant strain of *Plodia interpunctella* . Biochem. Biophys. Res. Comm. 198:940-947.

B. Oppert, T. D. Morgan, C. Culbertson, and K. J. Kramer. 1993. Dietary mixtures of cysteine and serine proteinase inhibitors exhibit synergistic toxicity toward the red flour beetle, *Tribolium castaneum.* Comp. Biochem. Physiol. 105C, 379-385.

T. D. Morgan, B. Oppert, T. Czapla, and K. J. Kramer. 1993. Avidin and streptavidin as insecticidal and growth inhibitory dietary proteins. Entomol. Exper. Appl. 69: 97-108.

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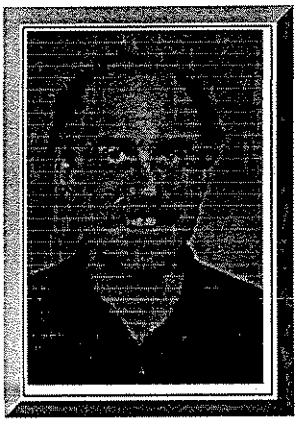

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Research Interests

Jame E. Throne is a research entomologist with the USDA-ARS at the U.S. Grain Marketing Research Laboratory in Manhattan, Kansas. He received his Ph.D. in Entomology from Cornell University in 1983; was a postdoctoral research associate at North Carolina State University from 1983 to 1985; and was at the USDA-ARS Stored-Product Insects Research and Development Laboratory in Savannah, Georgia, from 1985 to 1994. He specializes in the bionomics and management of agricultural insect pests, with emphasis on insect ecology and development of computer simulation models.

Current Research Projects

- Develop ELISA method for quantification of *Sitophilus* egg plugs in grain, for insect detection and ecological studies (Cooperators: Dr. Jim Baker, Dr. Karl Kramer, Dr. Don Silhacek, Dr. Rongda Xu)

- Identify corn varieties that are resistant to stored-product insects, and correlate resistance with chemical and physical properties of corn kernels (Cooperator: Dr. Jim Baker)

- Develop a computer model for simulating the population dynamics of the predator, *Lyctocoris campestris*, to determine its potential for use in biological control programs and to optimize release rates (Cooperators: Dr. Megha Parajulee, Dr. Tom Phillips)

- Develop a computer model for simulating the population dynamics of *Sitotroga cerealella* to optimize control strategies for this pest of stored corn (Cooperator: Dr. David Weaver)

-Refine a corn ecosystem model developed in cooperation with scientists at Purdue University, and use the model to assess the economic benefits of several non-chemical control strategies (Cooperators: Dr. Dirk Maier, Dr. Linda Mason)

-Develop and validate a computer model for simulating the population dynamics of the almond moth, *Cadra cautella* , on several stored commodities (Cooperators: Dr. David W. Hagstrum, Dr. Jan Nawrot).

Recent Publications

WEAVER, D. K., ZETTLER, J. L., WELLS, C. D., BAKER, J. E., BERTSCH, W., and THRONE, J. E. Toxicity of fractionated and degraded mexican marigold floral extract to adult, *Sitophilus zeamais* (Coleoptera: Curculionidae). J. Econ. Entomol. (In press)

MAIER, D. E., ADAMS, W. H., THRONE, J. E., and MASON,L. J. 1996. Temperature management of

the maize weevil, *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) in three locations in the United States. J. Stored Prod. Res. 32: 255-273.

THRONE, J. E. 1996. *Cryptolestes pusillus*. *In* Crop Protection Compendium for Southeast Asia and the Pacific, Center for Agriculture and Biosciences International, Wallingford, Oxon, UK. Compact Disk.

Adams, W.H., D.E. Maier, J.E. Throne, and L.J. Mason. 1995. Comparison of stored grain temperature management of maize weevil in three U.S. locations. American Society of Agricultural Engineers Meeting Presentation Paper 956122, 24 pages.

Baker, J.E., and J.E. Throne. 1995. Evaluation of a resistant parasitoid for biological control of weevils in insecticide-treated wheat. Journal of Economic Entomology 88: 1570-1579.

Baker, J.E., Weaver, D.R., Throne, J.E. and Zettler, J.L. 1995. Resistance to protectant insecticides in two field strains of the stored-product insect parasitoid *Bracon hebetor* (Hymenoptera: Braconidae). J. Econ. Entomol. 88: 512-519.

Parajulee, M.N., T.W. Phillips, J.E. Throne, and E.V. Nordheim. 1995. Life history of immature *Lyctocoris campestris* (Hemiptera: Anthocoridae): effects of constant temperatures and relative humidities. Environmental Entomology 24: 889-897.

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Throne, J.E. 1994. Life history of immature maize weevils (Coleoptera: Curculionidae) on corn stored at constant temperatures and relative humidities in the laboratory. Environ. Entomol. 23:459-1471.

Throne, J.E. and Cline, L.D. 1994. Seasonal flight activity and seasonal abundance of selected stored-product Coleoptera around grain storages in South Carolina. J. Agri. Entomol. 11:321-338.

Throne, J.E. and Cunningham, R.L. 1994. Ability of selected stored-product insects to infest polyurethane foams containing canary corn (maize) dextrin. J. Stored Prod. Res. 30:171-173.

Weaver, D.K. and Throne, J.E. 1994. Life history data for *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) in farm-stored corn and the importance of sub-optimal environmental conditions in insect population modelling for bulk commodities. *In* Proc. 6th Internat. Conf. Stored-Prod. Prot., Canberra, Australia, pp. 599-603.

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BIOLOGICAL RESEARCH UNIT SIGNIFICANT ACCOMPLISHMENTS - FY96

TEMPERATURE PREFERENCES OF RED FLOUR BEETLES were measured using acoustical sensors to monitor their movement along a temperature gradient in grain masses. Temperature preferences were strong enough to influence the predictions of insect population growth models during the spring and the fall when temperature gradients occur in stored wheat.
Dr. Hagstrum

DETERMINED TEMPERATURE THRESHOLDS for acute cold injury and internal freezing for 7 species of stored-product insect pests and one parasitoid species. These data will be used in insect population growth models to predict winter mortality.
Dr. Hagstrum; Dr. Burks

EXPERT SYSTEM FOR STORED GRAIN MANAGEMENT (Stored Grain Advisor) is being used by Oklahoma State University, Montana State University, and Kansas State University in their extension programs. It is being used in over 100 facilities storing over 100 million bushels of grain and will increase the use of IPM and reduce the use of chemicals.
Dr. Flinn

DEVELOPED THE FIRST COMPUTER MODEL OF THE PARASITOID WASP, cephalonomia waterstoni and rusty grain beetle population dynamics. This model predicts the population dynamics of the parasitoid and beetle over a wide range of temperature conditions. It was used to develop an optimal biological control program, and will be added to the Stored Grain Advisor expert system for stored grain management.
Dr. Flinn

GENES FROM INDIANMEAL MOTH CLONED. Genes for chymotrypsin- and trypsin-like proteinases from P. interpunctella were cloned, sequenced and analyzed. In addition, cDNA libraries were constructed from *Bt* resistant and susceptible insects. This information may prove useful in understanding a new, proteinase-mediated mechanism of *B.t.*-resistance.
Dr. Dowdy; Dr. Zhu

IMPORTANT GENETIC DIFFERENCES IN *Bt* RESISTANT AND SUSCEPTIBLE INSECTS IDENTIFIED. A *Bt* strain deficient in proteinase activity was shown to be lacking a major gut proteinase, and the lack of this proteinase appears to be important in *Bt* resistance.
Dr. McGaughey; Dr. Oppert

MATING FREQUENCY IN PARASITIC WASP DETERMINED. A genetic marker (malathion resistance) was used to determine mating frequency in a wasp that parasitizes grain pests. Results will help predict the penetration of resistance genes or other beneficial genes into field populations of this parasite.
Dr. Baker

INSECT MOLTING ENZYME GENE CLONED. For the first time a genomic clone for theinsect molting enzyme, chitinase, has been isolated. This gene is being developed as a bioinsecticide in transgenic plants and insect pathogens for host plant resistance and biological control purposes.
Dr. Kramer

NEW BIOINSECTICIDE GENE EVALUATED BY AGRICULTURAL BIOTECHNOLOGY COMPANY. A major seed company has been licensed to evaluate the insect chitinase transgene in transgenic plants for resistance to pest insects. This is a critical step in the commercial development of the transgene.
Dr. Kramer

NEW SYNERGIST FOR *Bacillus thuringiensis* ENDOTOXIN IDENTIFIED. The insect chitinase transgene was found to synergize the insecticidal activity of the endotoxin from the bacterium, *Bacillus thuringiensis*. This transgene might be a companion gene for that of the endotoxin in insect resistant transgenic plants.
Dr. Kramer

NEW METHOD FOR QUINONE ANALYSIS DEVELOPED. A new and improved method has been developed for the quantitative analysis of quinones that serve as important metabolites in animal, plant, and microbial metabolism. The method is more quantitative than previous methods and will enable scientists to more accurately determine endogenous levels of quinones in biological tissues.
Dr. Kramer; Dr. Xu

NEW INSECT CUTICLE CROSS-LINK STRUCTURES CHARACTERIZED. Using the latest developments in solid-state nuclear magnetic resonance techniques to measure interatomic distances between specific carbon, nitrogen, and oxygen atoms, new carbon-nitrogen and carbon-oxygen bonds between the proteinaceous building blocks of the insect exoskeleton have been detected.
Dr. Kramer; Dr. Xu

STORED-PRODUCT INSECT BIOTYPES DISCOVERED IN THE U. S. The existence of regional biotypes of a stored product pest (red flour beetle) was clearly demonstrated for the first time using a novel, naturally-occurring parasitic gene. The gene flow occurs from north to south, but not in the reverse direction. This research has applications in population monitoring and dispersal studies.
Dr. Beeman

GENE FOR OXIDATIVE RESISTANCE TO PESTICIDES CLONED FROM STORED- PRODUCT PEST. A fragment of a P450 gene associated with pyrethroid resistance was cloned from the red flour beetle. This accomplishment might lead to in vitro diagnosis methods for insect resistance to pyrethroid and related insecticides.
Dr. Beeman

INSECT HORMONE PRECURSORS FOUND TO VARY WITH DEVELOPMENTAL LIFE STAGE. Essential fatty acids that are converted to hormones used by insects to regulate immune responses to bacterial infection were shown to vary in both relative and absolute abundance between larval, pupal, and adult stages of beetle and moth species. These findings suggest that control of insect pests with microbial pathogens might be more effective in those life stages with lowest fatty acid reserves.
Dr. Howard

DELTAMETHRIN DUST CONTROLS STORED-PRODUCT BEETLES AND MOTHS. It was determined that a 0.05% deltamethrin dust formulation would control confused flour beetles for approximately 15 weeks and red flour beetles for approximately 20 weeks on concrete and tile. It was also evaluated as a treatment for wandering-phase Indianmeal moth larvae. Pupation and adult emergence generally decreased with increasing application rate and exposure time, but even highest label application rate gave effective control for only 4 weeks.
Dr. Arthur

GRAIN TEMPERATURE MANAGEMENT SYSTEM DEVELOPED in cooperation with Grain Science Department of Kansas State University for management of farm-stored corn. Aeration controllers were installed on eight bins, insect populations were sampled upon binning, and temperatures were monitored inside the bins.
Dr. Arthur

INSECT RESISTANT PACKAGES DEVELOPED for various food packaging companies that have lead to significant reduction in insect related complaints and to improve packages for export products.
Dr. Mullen

DEVELOPED NEW TECHNIQUES TO STUDY AND DEVELOP ODOR BARRIERS for use in insect resistant packages. Odor barriers were shown to be an effective method for reducing infestation of

packaged products.
Dr. Mullen

INDIANMEAL MOTH POPULATIONS identified by DNA fingerprinting. This procedure may be useful for determining at what point in the marketing channel that a commodity became infested and for monitoring changes in a population, such as development of insecticide resistance.
Dr. Dowdy

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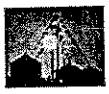
Biological Research Unit: Projects

Insect Modeling

Insect Resistant Packaging



Expert Systems

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Insect Molecular Genetics

Pyrethrin aerosol field demonstration trial

- Biological Control with Parasitoids and Entomopathogens
- Physiological and Genetic Controls
- Monitoring & Chemical & Physical Control Strategies
- Ecology, Modeling, and Integrated Management

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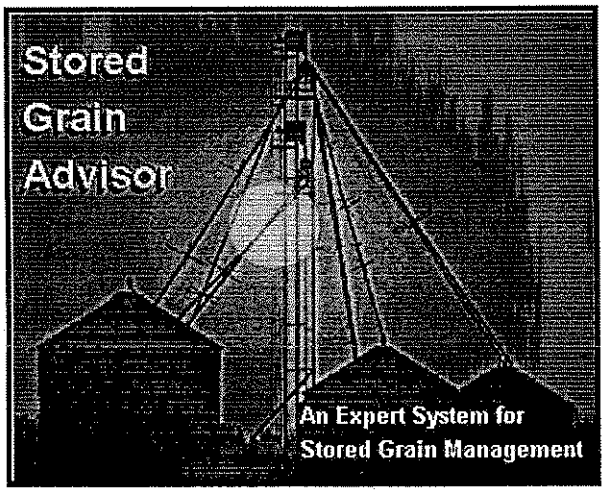
Welcome to the SGA Home Page

This site introduces you to SGA, the Stored Grain Advisor expert system.

- Download SGA
- **Download SGA manual**
  MS Word WordPerfect
- **View the SGA manual**
- **Use the SGA key to identify a stored grain insect pest.**
- **Dr. Paul Flinn**
- **Obtain disks & manuals from KSU**



Stored Grain Advisor (SGA) is a decision support system for stored grain management. It helps you make decisions about managing insect pests in stored wheat. SGA does this by predicting the likelihood of insect infestation, and by recommending appropriate preventative and remedial action. It also provides advice on how to sample and identify insect pests of stored wheat.

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Field demonstration trial with pyrethrin aerosols: Knockdown and recovery of confused flour beetles

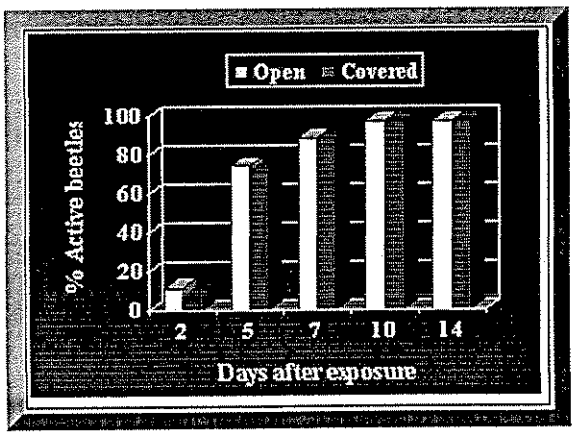
Dr. Frank Arthur

Synergized pyrethrin aerosols are used by the food industry to control insect pests inside mills and processing plants. There are several formulations and application systems on the market, and these systems are usually activated by a timing device to deliver a set dosage based on the cubic foot space of the facility. A typical mill contains machinery and equipment that block the free flow of aerosol fogs and could offer potential harborages for insect pests. The purpose of this demonstration trial was to determine the coverage and efficacy of several systems that were in operation at a flour mill in Des Moines, Iowa.

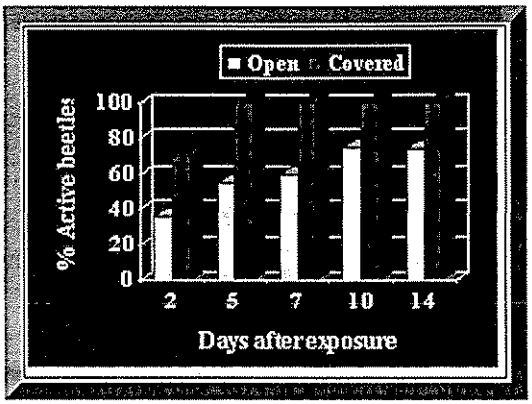
Three systems were in operation, a Turbicide Gold system (4% pyrethrins) in the mill, a CT-511 system (0.05% pyrethrins) in the mix packing area and the mill warehouse, and a ULD BP 300 system (3% pyrethrins) in the small pack-large pack bulk warehouse. The confused flour beetle, Tribolium confusum (DuVal) was used as the test insect species because it would not crawl upward or fly. Twenty aluminum dishes containing 10 1-2 week-old adults were placed at selected locations throughout the mill, 25 dishes of 10 adults were placed in the mix packing area, and 15 dishes of ten adults were placed in the small pack-large pack area. The position of each exposure dish was classified as open (no obstructions around the dish) or covered (dish partially or completely obstructed).

The systems were activated at approximately 4:30 PM and ran for up to 90 minutes, depending on the formulation. When the dishes were collected at 6:00 AM the next morning, all beetles were knocked down in 59 of 60 test dishes. The beetles in each dish were transferred to a clean Petri dish lined with filter paper. The Petri dishes were taken to the US Grain Marketing Research Center in Manhattan, KS, and held at laboratory conditions (approximately 72°F) along with two dishes containing 10 unexposed confused flour beetles. The beetles were examined after 2, 5, 7, 10, and 14 days, and classified as live (running freely in the dish), knocked down (on their backs but able to move) or dead + moribund (no visual movement).

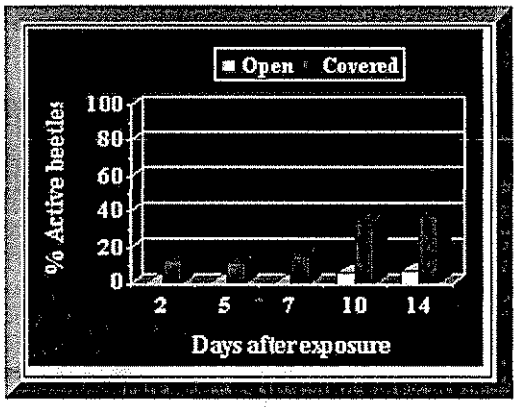
All beetles treated with the Turbicide Gold system were knocked down upon removal from the exposure sites but nearly 75% had recovered after 5 days. Recovery gradually increased during the holding period and by the conclusion of the test about 90% of the beetles had recovered from knockdown and were actively moving. There was no difference in recovery between beetles exposed in open positions versus covered positions.



Similar patterns of recovery were observed for beetles exposed to the CT-511 system in the mix-packing plant. All beetles were knocked down upon removal from the exposure environment with the exception of 3 individuals in one dish. However, by the conclusion of the test approximately 75% of the beetles exposed in the open positions had recovered. All beetles exposed in the covered positions had recovered by 5 days post-exposure.



Recovery of beetles exposed in the open warehouse was greater in the covered sites than in the open sites. At the end of the 14-day holding period only 7% of the beetles from open sites had recovered from knockdown versus 38% recovery from covered sites. The warehouse contained processed products boxed and stacked on pallets but did not have machinery and equipment that could obstruct aerosol particle movement. The aerosol treatment was more effective in the warehouse than in the mill or the mix-packing plant.



In conclusion, confused flour beetles were knocked down by all three aerosol application systems, but recovery was nearly 100% in the mill environment regardless of where the exposure dishes were located. The best kill was in the open warehouse. Obstructions inside mills may restrict movement of pyrethrin aerosols, but the effects of these obstructions may be dependent upon the specific formulation and dispensing equipment. The results of this demonstration trial must be replicated before drawing conclusions regarding the insecticidal efficacy of these specific application systems.

Back to Dr. Arthur's Page

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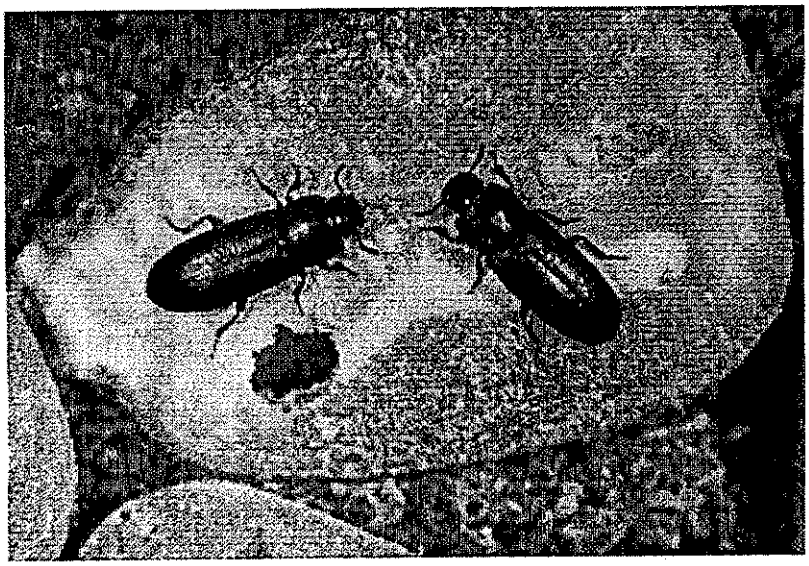
Welcome to the *Tribolium* Home Page

This site contains data and articles about the genetics of the red flour beetle, *Tribolium castaneum*, and related species. Work being done in Dr. Beeman's laboratory involves both standard and molecular approaches.

- Standard Genetics
  - Beetle Handling
  - Linkage Maps
  - Mutants
- Medea: Maternal-Effect Selfish Genes
- Insecticide Resistance in *Tribolium*

- Search the *Tribolium* Web Site
- Download these Web Pages for local use on your PC.



To Dr. Beeman's Page

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Send comments or questions to
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Last Edited: June 27, 1997
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Host and Parasitoid Rearing (Dr. Paul Flinn)

Technician: Ken Friesen Frames Version

Abbrev.	LGB	RGB		STGB	
Common Name	Lesser grain borer	Rusty grain beetle		Sawtoothed grain beetle	
Scientific Name	*Rhyzopertha dominica*	*Cryptolestes ferrugineus*		*Oryzaephilus surinamenis*	
Parasite	*Choetospila elegans*	*Cephalonomia waterstoni*		*Cephalonomia tarsalis*	
Grain moisture	10-12%	13%		13%	
Chamber temp.	30°C	30°C		30°C	
Chamber humidity	60% RH	75% RH		75% RH	
Unit	Quart	Quart	Pint	Pint meth. 1	Pint meth. 2
Wheat	full: whole grain	300 ml crimped; balance whole	none	full: crimped	half: crimped
Brewer's yeast	none	1/4 tsp	1 Tbsp	1 tsp	1 tsp
Wheat germ	none	1/4 tsp	1 tsp	none	none
Other	1/4 tsp flour	none	1/2 pint flour	none	half rolled oats
Starting # adults	100	400 (0.3 ml)	100	75	50

INDEX

Index

Transferring insects
- Equipment
- Media
- Tips and tricks

LGB - Quart
- C. elegans (host: LGB) - gallon
- C. elegans (host: LGB) - pint

RGB - Quart
RGB - flour - pint
- C. waterstoni (host: RGB) - gallon
- C. waterstoni (host: RGB) - pint

STGB - pint - method 1
STGB - pint - method 2
- C. tarsalis (host: STGB) - pint
- C. tarsalis (host: STGB) - gallon

Equipment

When working seriously with stored grain product insects, certain tools and 

supplies are necessary. These include sieves and seed pans, which can be purchased from Seedburo Equipment Co., Fisher Scientific, or other analytical supply companies. Most of the tools in the following list are available from the above, or can be improvised.
(Commercial Endorsement Disclaimers)


Seedburo Equip.

- **Sieves** - Various sizes of U.S. Standard sieves are used to clean grain and to separate insects form the grain. Separate sets of sieves are recommended for each type of insect, to avoid cross-contamination.
- **Spouted sample pans** - Sample pans are extremely useful for handling insects and grain.
- **Rearing containers** - Various sizes of canning jars will serve to rear insects, provided the band contains a 7.0 cm circle of filter paper instead of the cap. Also, gallon jars and five gallon buckets will work, if a fine mesh is fitted into the lid.
- **Rearing chambers** - Chambers with reliable temperature and relative humidity controls are very important in most cases.
- **Aspiration** - It is useful to have some form of vaccum system (mouth or mechanical) to aid in collecting insects by means of a trap system.
- **Brushes** - Different sizes and fiber types help manipulate and handle insect cultures.
- **Microscope** - Periodically, a microscope will be necessary to identify or separate insects.

TOP INDEX

Media

- **Grain**
  - **Aquiring wheat** - Wheat needs to be of average to good quality, and pesticide free. The best method is is obtaining the wheat directly from the producer.
  - **Cleaning** - It is desireable to clean the wheat 1-2 times before rearing insects. This can be done with hand sieves for small volumes, or some form of mechanical sieve or dockage tester may be used if needed and available.
  - **Moisture** - Low moisture wheat may need to be tempered with the appropriate ammount of water to adjust it to optimal rearing properties. High moisture wheat needs to be guarded against molding before use.
  - **Storage** - Ideally, grain for rearing insects would be frozen and then stored at 15°C or cooler, until a few days before it is needed. This protects against insect and fungal growth.
  - **Crimped wheat** - This is wheat which has been crushed or deformed to a moderate degree in order to increase the insects' access to the germ.
- **Additives** - Flour, oatmeal, wheat germ and brewer's yeast can be purchased at most supermarkets or health food stores. It is convenient if the flour and wheat germ are fine enough to pass through a #40 sieve.

TOP INDEX

Tips and Tricks

- Wasps are quick and good climbers- be alert and quick, but gentle.
- STGB are good climbers - watch closely.
- Wasps can be handled well w/ a camel hair brush, small funnel, and tefloned bottle. Static charge can can be defeated by breathing on the affected item.
- RGB can sort themselves from fine material if poured onto a petri dish lid positioned properly in a pan.
- Avoid high densities and poor ventilation to avoid carbon dioxide selection.
- Periodically wash insect-handling equipment with hot water and a distilled water rinse

TOP INDEX

LGB - Quart

LGB : lesser grain borer (Rhyzopertha dominica)

- ☐ 600 g whole wheat (or full)
- ☐ 1/4 tsp fine flour (mixed in: stimulates egg-laying)

- ☐ Prev. jar sifted w/ #14 & #30 sieve
- ☐ Contents of #30 (adults) put on new media
- ☐ Grain and fine materials returned to prev. jar
- ☐ Record oviposition and seed dates

- ☐ Use 100 seed adults
- ☐ Seed adults replaced every 2 months
- ☐ Oviposition time is a week
- ☐ Generation time is about 30 days
- ☐ Chamber temp. 30°C
- ☐ Chamber humidity 60% RH
- ☐ wheat moisture 10-12%

TOP INDEX

C. elegans (host: LGB) - gallon (continuous culture)

- ☐ Add 1/2 Quart of 3 to 4-week-old LGB culture to top of gallon jar
- ☐ When gallon is full (to shoulder), dump top 1/3 into new jar, and add food.
- ☐ Feed weekly

TOP INDEX

C. elegans (host: LGB) - pint

- ☐ Add 1-2 inches of 3-4 week-old LGB culture to pint jar

- ☐ Prev. jar of C. elegans sifted w/ #14, #40, & #70
- ☐ Return grain
- ☐ 12-15 adult wasps added infested grain
- ☐ Record oviposition and seed dates

- ☐ Oviposition time is 10 (9-14) days
- ☐ Seed number is 12-15 wasps
- ☐ When harvesting wasps, use a subset of the new wasps to propagate the culture
- ☐ Sift wasps gently
- ☐ Wasps are quick and clingy - be alert and quick, but gentle
- ☐ Generation time is 14-19 (most 16) days
- ☐ Chamber temp. 30°C
- ☐ Chamber humidity 75% RH

TOP INDEX

RGB - Quart

RGB : rusty grain beetle (Cryptolestes ferrugineus)

- 400 g whole wheat (2/3 jar)
- 200 g crimped wheat (1/3 jar)
- 1/4 tsp wheat germ (#40)
- 1/4 tsp brewers yeast
- All mixed

- Prev. jar sifted w/ #14 & #40 sieve
- Contents of #40 (adults) put on new media
- Grain and fine materials returned to prev. jar
- Record oviposition and seed dates

- # of seed adults is 400 (0.3-0.4 ml)
- Seed adults replaced every 2 months
- Throw dead adults out to prevent disease
- Oviposition time is a week
- Generation time is about30 days
- Chamber temp. 30°C
- Chamber humidity 75% RH
- wheat moisture 13%

TOP INDEX

RGB - flour - pint

RGB : rusty grain beetle (Cryptolestes ferrugineus)

- < 1/2 pint flour (#40)
- 1 tsp wheat germ (#40)
- 1 Tbsp brewers yeast
- All mixed (can make a premix)

- Prev. jar sifted w/ #40 sieve
- Flour returned to prev. jar
- Adults put on new media
- Record oviposition and seed dates

- # of seed adults is 100
- Seed adults replaced every 2 months
- Throw dead adults out to prevent disease
- Oviposition time is a week
- Generation time is about 30 days
- Chamber temp. 30°C
- Chamber humidity 75% RH
- wheat moisture < 13%

Pre-mix media for RGB

- Divide gallon of flour in half, add 10 Tbsp of brewer's yeast and 10 tsp wheat germ to each, then mix well.

TOP INDEX

C. waterstoni (host: RGB) - gallon (continuous culture)

- Add 1/2 Quart of 3 to 4-week-old RGB culture to top of gallon jar
- When gallon is full, sift w/ #14, #40, #70 sieves to retrieve wasps
- Put recovered wasps on 1/2 Quart of 3 to 4-week-old RGB culture, in new gallon jar
- Feed weekly

TOP INDEX

C. waterstoni (host: RGB) - pint

- Use #40 to sift out late instar (4th) larvae from 3-4 week old RGB (C.f.) jar
- Put 50-60 of these larve into 1 inch of wheat, in pint

- Prev. jar of C. waterstoni sifted w/ #14, #40, & #70 (don't bother cocooned materials)
- Return everything, or at least cocoons
- Adult wasps added to RGB larvae
- Add rehydrated raisin
- Record oviposition and seed dates

- Oviposition time is 10 (9-14) days
- Seed number is 20 wasps
- Supplement wasps as needed with new wasps
- Sift wasps gently
- Wasps are quick and clingy - be alert and quick, but gentle
- Generation time is 14-19 (most 16) days
- Chamber temp. 30°C
- Chamber humidity 75% RH

TOP INDEX

STGB - pint (method 1)

STGB : sawtoothed grain beetle (Oryzaephilus surinamenis)

- Fill pint with crimped wheat
- 1 tsp brewers yeast
- All mixed

- Prev. jar sifted w/ #14 & #40 sieve
- Oats and fine material returned to prev. jar
- Adults put on new media
- Record oviposition and seed dates

- # of seed adults is 100
- Seed adults replaced every 2 months
- Throw dead adults out to prevent disease
- STGB are good climbers - watch closely
- Oviposition time is a week
- Generation time is 3-4 weeks
- Chamber temp. 30°C
- Chamber humidity 75% RH
- wheat moisture 13%

TOP INDEX

STGB - pint (method 2)

STGB : sawtoothed grain beetle (Oryzaephilus surinamenis)

- 1/2 pint crimped wheat
- 1/2 pint rolled oats
- 1 tsp brewers yeast
- All mixed

- Prev. jar sifted w/ #14 & #40 sieve
- Oats and fine material returned to prev. jar
- Adults put on new media
- Record oviposition and seed dates

- # of seed adults is 100
- Seed adults replaced every 2 months
- Throw dead adults out to prevent disease
- STGB are good climbers - watch closely
- Oviposition time is a week
- Generation time is about 3-4 weeks
- Chamber temp. 30°C
- Chamber humidity 75% RH
- wheat moisture 13%

TOP INDEX

C. tarsalis (host: STGB) - pint

- Use #14 & #40 to sift out late instar (4th) larvae from 2-3 week old STGB (O.s.) jar
- Put 50-60 of these larve into 1 inch of wheat, in pint

- Prev. jar of C. waterstoni sifted w/ #14, #40, & #70 (don't bother cocooned materials)
- Return everything, or at least cocoons
- Adult wasps added to STGB larvae
- Add rehydrated raisin, honey water or sweetened cotton
- Record oviposition and seed dates

- Oviposition time is 10 (9-14) days
- Seed number is 20 wasps
- Supplement wasps as needed with new wasps
- Sift wasps gently
- Wasps are quick and clingy - be alert and quick, but gentle
- Generation time is 14-19 (most 16) days
- Chamber temp. 30°C
- Chamber humidity 75% RH

TOP INDEX

C. tarsalis (host: STGB) - gallon (continuous culture)

- Add 1/2 Pint of 2 to 3-week-old STGB culture to top of gallon jar
- When gallon is full, sift w/ #14, #40, #70 sieves to retrieve wasps

- ☐ Put recovered wasps on 1/2 Quart of 2 to 3-week-old STGB culture, in new gallon jar
- ☐ Feed weekly

TOP INDEX

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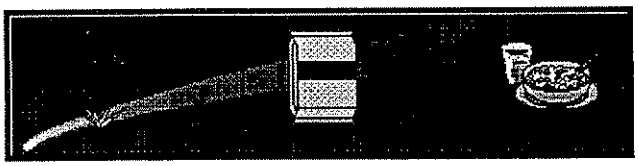
Role of Insect Resistant Packaging for the Protection of Processed Grain Products

Dr. Michael A. Mullen

Packages should protect the commodity from the point of manufacture to the point of consumption.



Packaging is a system with the objective of protecting the product against various hostile environments including insects.

A packaged commodity is the point at which the customer has first contact with the product and consumer goodwill is either lost or established.

Sanitation programs have often been reduced or even eliminated at various points along the distribution chain.

A packaged commodity is a value added product because it has undergone the cost of growing, harvesting, processing, packaging, transportation, and storage.

The food industry faces increasingly restrictive regulatory requirements regarding pesticide use.

Insect resistant packaging has been shown to be an important way to reduce dependence on insecticide treatments.

There is a direct correlation between package seals and swiftness of infestation. Packages can often be improved by changing the glue or glue patterns.

One indicator of potential infestation is the

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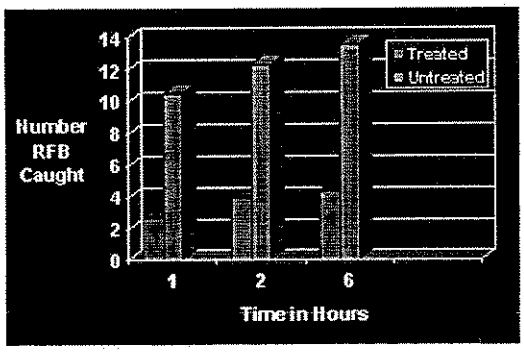
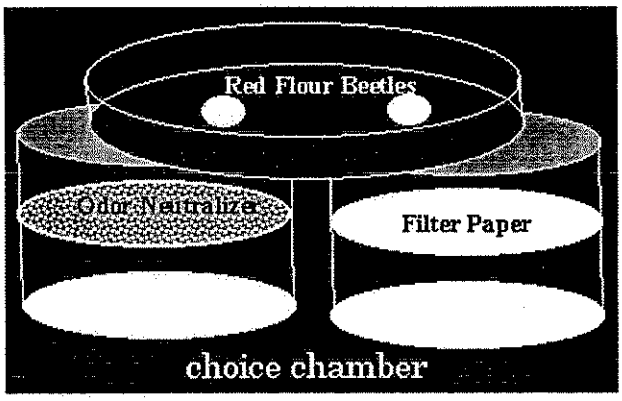
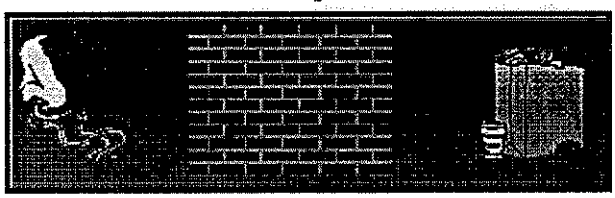


One indicator of potential infestation is the attractiveness of a particular food to the pest insects. In this test dry dog food treated with an odor neutralizer was significantly less attractive to red flour beetles than untreated dog food.

A choice chamber was developed to test the attractiveness of food treated with an odor neutralizer. These tests were conducted by placing a treated or untreated filter paper disk between the insects and the food to be tested. Insects released in the upper part of the chamber had a choice to go to the treated or untreated side. The number of insects attracted to each side was used as an indicator to determine the effect of the odor neutralizer.



Odor barriers reduce the potential for infestation.



Dr. Michael A. Mullen

Last Edited: October 15, 1996
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Movement of Rusty Grain Beetle in Response to Temperature Gradients in Stored Wheat

Paul W. Flinn and David W. Hagstrum

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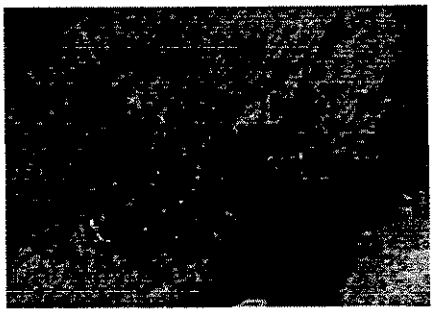
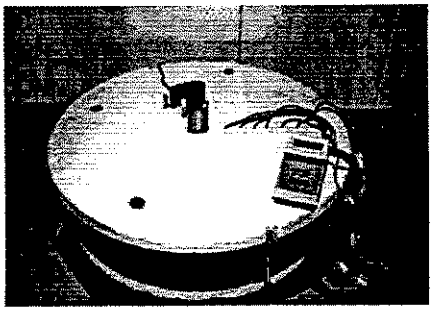
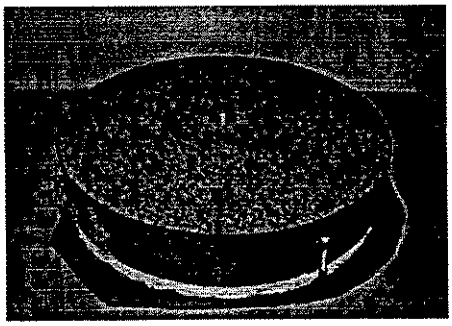


The rusty grain beetle, *Cryptolestes ferrugineus*, is the most common insect pest of stored wheat in the United States and Canada. Adults and larvae feed mostly on the wheat germ and cause considerable damage. Beetle population growth rate is primarily affected by grain temperature. In the fall, the periphery of the grain mass cools more rapidly than the center. Beetles often reach high densities in the center of the grain mass, because warmer temperatures there allow the population to increase during the winter. Beetle populations may also be higher in the center if they are able to move from the cool periphery towards the warm center of a grain mass. However, temperature gradients in a grain bin are often small (5°C/m), so it may be difficult for insects to locate warmer regions of a grain mass. To predict rusty grain beetle population growth in bins, we need to know if they move towards and remain in warmer regions of a grain mass.

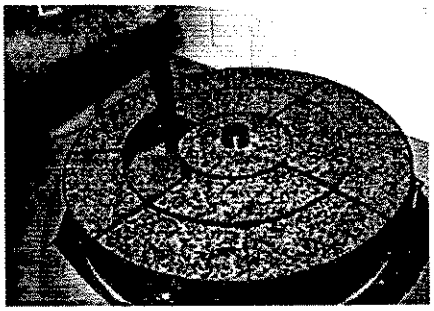


The test arena consisted of a 56 cm diameter cylinder with 9 cm high metal sides, and insulated top and bottom. The cylinder was filled with hard red winter wheat (12% moisture). A temperature gradient was established by heating the center of the cylinder with an aquarium heater immersed in a water bath. The perimeter of the cylinder was cooled to 20°C by keeping the arena in an environmental chamber maintained at 20°C. The chamber was kept at 30°C for the no-gradient experiment.



After establishing the temperature gradient for 24 hours, 98 adult rusty grain beetles were evenly distributed over the grain surface and the insulated top was secured to the cylinder.

Twenty-four hours later, the top was removed and a metal divider was inserted into the grain that partitioned the cylinder into 13 compartments. The grain was removed from each compartment using a vacuum device and sieved for insects.



After 24 hours, rusty grain beetles moved into and remained in the warm center of the grain mass in the high, moderate and low temperature gradients. Insects remained evenly distributed throughout the grain mass when there was no temperature gradient.

When a temperature gradient was established, insect densities were 10 times higher in the center compartment than in the middle or outer compartments. With no temperature gradient, insect density was not significantly different between the center, middle, and outer compartments.

Summary

Insects moved into and remained in warmer areas of the grain mass after 24 hours. Beetle preference for the warmest area of the grain mass occurred at 42-20°C, 24-20°C, and 21-20°C temperature gradients. The beetles were able to locate the warmest area even at the smallest gradient of 3.7°C/m (1°C/0.27m). Grain stored in bins cools fastest on the outside and remains warmer longer in the center. In the fall, gradients often reach 7-10°C/m (Hagstrum 1987). This study suggests that rusty grain beetles should move toward the warmer, inner regions of a grain mass as the periphery of the grain cools in the fall. Beetles should also move toward the periphery of the grain mass as it warms in the spring. This movement will be incorporated into a spatial model of rusty grain beetle population dynamics (Flinn et al. 1992).

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18. TECHNIQUE

19. TERATOLOGY

RESEARCH, TEACHING AND TECHNICAL NOTES

*Infestation of Cashew Kernels by *Tribolium confusum* and Other Stored Product Insects

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Of all the tree nuts imported into the United States of America, cashews are the most economically important shelled nut. Infestation by stored product insects is a matter of great concern because expensive procedures are required to kill and remove the insects and insect damaged kernels. The major pest of stored cashew kernels is *Tribolium confusum*, which can be found in shipments from all origins. In response to this problem, the Association of Food Industries (AFI), an organization of importers, food brokers, and food processors, has established a tolerance of 0.5% for insect damaged cashew kernels (AFI 1997). This limit is stricter and more relevant than the FDA Defect Action Level of 5.0% for shelled cashews. Many shipments of cashews are independently inspected before shipment and again upon arrival in the USA. Some of the shipments that are not independently inspected are examined by in-house quality control personnel. These efforts are sometimes unsuccessful in detecting infested lots because of ineffective sampling and inspection procedures, cursory macroanalytical methods, and misinterpretation of results. To remedy this situation, persons responsible for inspecting cashews need to have a better understanding of cashew packaging, the process histories of the producers, and the behavior of *T. confusum*. Inspections will always be necessary, but improved packaging, modified atmospheres and better sanitation are the key to controlling these stored product pests.

The cashew tree, *Anacardium occidentale*, grows in a region roughly twenty-five degrees of latitude north and south of the equator (Ohler 1988). The shelled nuts are imported into the USA, principally from India, Brazil, Mozambique, Kenya and Vietnam. Damage from stored product insects has been a major concern since the first shipment of cashews was imported into the USA from India in the early 1920s. The size of a typical lot of cashews is seven hundred cartons, each holding fifty pounds of kernels, which is the quantity that can be loaded into a twenty foot intermodal shipping container. If the lot is seriously infested, the loss due to treatment and reconditioning costs can exceed $25,000.00, or nearly one third of its value.

Cashews are packed into four gallon tins, four gallon molded plastic bags, or eight gallon flexible foil packages. After these packaging units are filled, a vacuum is drawn and the oxygen is replaced with a modified atmosphere of carbon dioxide. Two twenty-five pound net tins or molded plastic bags are packed into a master carton. In the case of the flexible packages, a single foil bag holding fifty pounds is packed into each carton. The packaging system that is used has a significant effect on the quality and condition of the product. Most shipments from Mozambique are now packed in the newer molded vacuum packages (MVP), while Brazilian exporters favor the flexible foil bag. In Vietnam and India, only tins are presently used; although, producers in India are investigating the MVP system.

The highest frequency of infestation occurs in cashews packed in poor quality single-

seam tins which fail to maintain the modified atmosphere. Given that the lethality of CO_2 atmospheres to adults of *T. confusum* has been well established (Aliniazee 1977), good manufacturing practice dictates that only double-seam high quality tins be used.

The search for *T. confusum* and other stored product insects in cashews begins with an understanding that these lots are not homogeneous. Lots are composed of product that may have been packed over a period of several weeks and often at several small factories. Cartons compiled for a shipment may each have identical brand marks and code numbers, but their contents often vary greatly in one or more attributes. Insect infestation is usually very random and a sufficient number of random samples must be drawn in order to detect a problem. The AFI has established an acceptance sampling plan for cashews, a modification of the USDA plan for "Similarly Processed Fruits, Vegetables, and Products Containing Units of Such Size and Character as to be Readily Separable" (USDA-AMS 1981). This was meant to be used as an acceptance sampling plan (Table 1), but debate over the use of acceptance or rejection numbers resulted in the omission of this vital part of the plan from the current AFI Cashew Specification.

It is important to think of tins and vacuum bags as closed systems, unlike burlap sacks, cartons with paper liners, and other packaging systems that are readily invaded by insects. In addition, it should be noted that in most infested cashew packages only adults of *T. confusum* are found, without any evidence of larval activity. These beetles are invaders and cannot penetrate sealed tins or foil bags. Pyralid larvae and adult *T. confusum* are also unlikely to penetrate the polypropylene bags used in the MVP system (Bowditch 1997). Therefore, when such a packaging unit is infested with only adults, it follows that the insects must have been randomly packed into the tins or bags with the product. Clearly the pests did not develop from eggs and pass through metamorphosis in storage, anymore than they could have migrated from another sealed tin. An inspection should therefore follow an acceptance sampling plan based on attributes. There are three questions to ask: is the sample unit infested, are the insects alive, and is there significant kernel damage? If the answer to any one of these questions is yes, the sample unit fails the specification.

In practice, whole or equivalent insects collected by sieving are categorized by degree, as either Class I (none detected), Class II (< 10 insects), and Class III (> 10 insects). The acceptance number would apply to Class II subsamples only. If there is more than the acceptance number of Class II subsamples, or one or more Class III subsamples are found, the lot fails to meet the specification. The proper application of an acceptance sampling plan is a necessary tool in determining whether or not a product is seriously infested.

Table 1. Acceptance sampling plan for cashew nuts.

Lot size (cartons) number	number of sample units	Class II acceptance
≤ 50	3	0
51 - 350	6	1
351 - 700	13	2

Each tin or bag that is sampled should be passed over a 12 inch, US or Tyler equivalent number 4 sieve and pan, or conveyed over a vibrating screen with equivalent openings. It should be noted here that many methods require a No. 8 sieve, but this sieve size will retain some of the adults of species that infest cashews, and they may go undetected. The material collected in the pan, and the interior of the tin or bag should be examined for webbing, frass, and insects. When collecting samples, a 500g portion is drawn from each sampled unit, and examined for insect damage. The macroanalytical procedure used by FTS Laboratories requires that 100 kernels (or 100g of pieces for broken grades) be examined from each subsample; however, if there was no evidence of infestation at the time of sampling, a composite portion of 1,000g is examined. In contrast, FDA follows a sequential procedure outlined in the Macroanalytical Procedures Manual (FDA 1984), in which as few as 100 kernels might be examined, from a composite sample.

T. confusum will be found at the bottom of the tin or bag and the first sign of infestation is usually a powdery residue of excreta. The larvae of *T. confusum* will preferentially enter the cavity of a cashew kernel through any natural opening; such as, a separation of the cotyledons or the hole created when the plumule is missing. The larvae feed and grow in the center cavity until the last instar, at which point the larvae tunnel into the kernel making a chamber for the pupal stage. Adults will normally not enter the cavity after they have emerged, and cause only superficial damage to the exterior surfaces of the kernel..

Necrobia rufipes is sometimes found in cashews from India and Mozambique and the adults, as well as the larvae of this species cause a great deal of damage by boring large holes in the kernel. *N. rufipes* is predaceous and cannibalistic (Gentry et al. 1991 and Hill 1990) which may explain why it is not found in large numbers in cashew infestations, and rarely with *T. confusum* and other pests.

Infestation by *Oryzaephilus surinamensis* is common in cashews, and is found more often in product imported from Africa, and nuts processed in China. Occasionally, *O. surinamensis* is found together with *T. confusum* in heavy infestations, but both larvae and adults of *Tribolium spp.* are predators of *Oryzaephilus spp.* (Hill 1990), and in less severe infestations they are not usually seen together.

Other coleopteroids, *Carpophilus ssp., Lasioderma serricorne, Tenebriodes mauritanicus,* and *Cryptolestes spp.*, are infrequent and usually secondary pests found in heavy infestations. A report of cashew kernels infested with "weevils," is probably a matter of the misuse of a common name. I have analyzed more than 500,000 samples of cashew nuts from all origins and have never personally observed curculionids infesting this product, but it is of course possible.

Pyralid larvae of *Cadra cautella, Plodia interpunctella* and *Corcyra cephalonica,* are found infesting cashews from all origins, but more often in product imported from Brazil and India. Webbing from the larvae of pyralids will be found at the top, sides, and corners of the package. In serious infestations there will be clumped masses of webby kernels. Webbed excreta trailing out from a hole at one end of the kernel is also evidence of lepidopteran larvae. Food processors often mistakenly refer to these characteristic clumps of webbed excreta as eggs. The larvae will enter the center cavity, but are often too large to pass through natural openings, so they will gnaw a larger hole or bore directly through the kernel. Pupal stage pyralids will usually be found in the center cavity, but when this area is too small, they will attach themselves to the exterior of the kernel. Damage caused

by these pests is of the greatest concern to food processors because webbing is readily apparent to consumers it is very difficult to remove by reconditioning. Pyralids are preyed upon by *Tribolum ssp.* (Hall 1990), which is probably why they do not appear in significant numbers when *T. confusum* is present.

When live insects are found, the infested lot is treated by placing the product in freezer storage. According to Cotton (1950), the time required to kill all stages of *T. confusum* and other common stored product insects is 24 hours at -18°C (0°F). Lots are usually held in freezer storage for more than a week to ensure that the cold has penetrated to the center of all of the packages. The product can also be heat sterilized at 60°C (140°F) for 10 minutes. Both methods are employed, and some food processors prudently treat all shipments as a quality control measure. Cashews should never be fumigated with methyl bromide, because a reaction occurs between the fumigant and the amino acid methionine. This produces an intermediate compound which during roasting will break down to dimethyl sulfide causing a strong off flavor.

After the insects are killed, larvae that are not in the center cavity and adults are removed by screening. Kernels with webbing are hand picked on conveyed inspection lines. Packages with evidence of center cavity damage are either destroyed or the contents are broken into pieces, screened, and picked.

It is interesting that although *T. confusum* is dominant in cashews, *T. castaneum* is apparently not a cashew pest. A comparison of the nutritional requirements of these two species and the availability of required nutrients in cashews would be very interesting. I have entertained myself by placing *T. castaneum* adults and larvae (instar not noted) on a dish with a cashew kernel and a cracker. Both stages investigated the substrates, but the larvae remained on the cashew, while the adults remained on the cracker. Clearly I did not follow sound scientific methods, but the result did lead me to speculate on selection of oviposition sites as a reason for the absence of this species in cashew infestations.

In another instance, I placed a cashew, a filbert, and a Brazil nut in dish, alternately with *O. surinamensis* (adults and larvae), *T. confusum* (adults and larvae) and *P. interpuctella* (larvae). In each case, the insects fed on the cashew and ignored the other types of nut meats. This was also an informal observation, but it suggests that studying the nutritional aspects of cashew kernels with respect to several stored product pests may be helpful in finding ways to reduce infestation.

Stored product research will continue to play an integral part in reducing economic losses due to *T. confusum* and other pests of cashew kernels. Sound packaging, sustained modified atmospheres, better sanitation in the factories, and more effective inspections will help to control infestation in cashew kernels. Ultimately, it is the exporter, importer, and food processor who must learn these lessons and ensure that the new technology and good manufacturing practices are applied.

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Notes - Research, Teaching and Technical

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* Two mutants of Tribolium castaneum.

1. Bge (bug-eyed) - Spontaneous recessive mutant found in the Georgian (Ga-1) wild type stock. The eye is larger than in wild type, having an extra row of ommatidia, measured anterior to posterior (A-P) at the genal shelf. The larger eye increases the actual width of the head. Ventrally, the head has the widened appearance of Cx (Cephalothorax) mutants., but without the deeply cleft gular sutures. The gular sutures do appear slightly more indented at their anterior end than those of wild-type. Strength of expression is variable. Shallow dents on the dorsal pronotum also characterize this mutation.

2. cfl-2 (confusum-like) - Spontaneous recessive found in the dominant Bamp31 stock. The eye is smaller than in wild type, having one less row of ommatidia, measured A-P at the genal shelf. The ventral margin of the eye recedes from midline, creating more space between the eyes, and thus, producing a confusum-like (T. confusum) appearance. Probably allelic to the no-longer available mutant described by Sokoloff (Sokoloff, A. 1976. Morphological traits and classification of Tribolium. Tribolium Inf. Bull 19:111-113).

SIRE AND PERIOD DIFFERENCES FOR LARVAE NUMBER IN *TRIBOLIUM CASTANEUM*

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Total number of larvae produced by a dam which is a major component of fitness value is found to be influenced by different environmental factors like humidity (Haldaway, 1932), temperature (Howe, 1956) and density of eggs (Bartlett, 1962). However, media was found to have no significant effect on hatchability (Park, 1937). The present study was undertaken to investigate sire and period differences for larvae number in *Tribolium castaneum*.

The base population used in this investigation was established at Population Genetics Laboratory, Indian Veterinary Research Institute, Izatnagar (UP), India by collecting beetles from flour mills in Izatnagar and random mating. This population had undergone about 12 generations of random mating at the time of starting this investigation. The beetles were raised in the media consisting of 95 parts of whole wheat flour, 4 parts of dried yeast powder and 1 part of vitamin mixture (A, B_2 and D_3) and were maintained in a BOD incubator at a temperature of 31±0.05°C and relative humidity of 70±5 percent. Sexing was done at pupal stage.

A total of 12 males and 36 females were taken at random from the base population. All the beetles were newly emereged. Each male was mated with 3 females randomly. Mating was allowed for 4 days continuously. After completion of mating, beetles were kept in separate vials for 7 days for egg collection and thereafter they were transferred to main stock. The checking of vials for larvae number started after 7 days of egg collection and was continued for next 9 days. The data were

analysed using least squares and maximum likelihood computer package (Harvey, 1987) using following model:

$$Y_{ijk} = \mu \pm S_i \pm D_j \pm e_{ijk}$$

where, Y_{ijk} is the observation of a beetle for larvae number with the following subscripts, μ is overall mean, Si is the fixed effect of ith sire, D_j is the fixed effect of *jth* day of larva number recording and e_{ijk} is random residual error.

The total number of larvae per female increased or decreased in different days and did not show a unique trend. The increase in larvae number was due to hatching of eggs laid during later days of egg collection period. The reduction in larvae number was because of mortality in larvae or cannibalism. The results showed that 34% females produced maximum number of larvae on 6th day of recording. About 17 % females produced their maximum larvae on 2nd day. Only 3 percent females showed their maximum progeny on 3rd, 8th or 9th day. The number of larvae produced from 7 day egg collection averaged 32.82 ranging from 2 to 54. Informations on larvae number produced during above period are scanty. However, Ruano and Orozco (1966) reported fecundity of *Tribolium castaneum* females in 4 day period between the fourth and seventh day after adult emergence as 67±11 eggs. Park (1933) observed the fecundity of females kept with their mates for 11 days averaging 16 eggs per day.

Sire effect was found to be significant on larvae number (Table1). Average number of larvae ranged from 16 (sire 10) to 42 (sire 5) and is presented in Table 2. This variation shows that sire selection for 7 days larvae number may improve this trait. It corroborates the findings of Krause and Bell (1971) who observed the heritability of larval number as 0.33 in the black strain of *Tribolium castaneum*. Day of recording had no effect on average larvae number. It does not indicate that within

female , there is no variation for larval number over period, but shows that the average larvae number had uniform curve from 1st to 9th day of recording (Figure 1).

Table 1. Least squares analysis of larvae number.

Source	df	SS	MS	F
Sire	11	18593	1690	12.35**
Day	8	1658	207	1.51
Error	286	39122	136	

**Significant ($P < 0.01$)

Table 2. Least squares means of larval number for various levels of sire group and day of recording

Sire Group	Least squares mean	Standard error	Day of recording	Least square mean	Standard error
1	24.53	2.25	1	24.17	2.01
2	20.88	2.25	2	29.08	2.01
3	30.94	2.75	3	28.48	1.98
4	21.18	2.25	4	29.78	2.08
5	42.18	2.25	5	30.00	2.00
6	25.62	2.25	6	33.32	2.01
7	23.49	2.25	7	31.17	1.98
8	25.74	2.25	8	30.69	2.03
9	36.59	2.25	9	29.29	2.01
10	16.77	2.25			
11	35.22	2.75			
12	31.51	2.25			

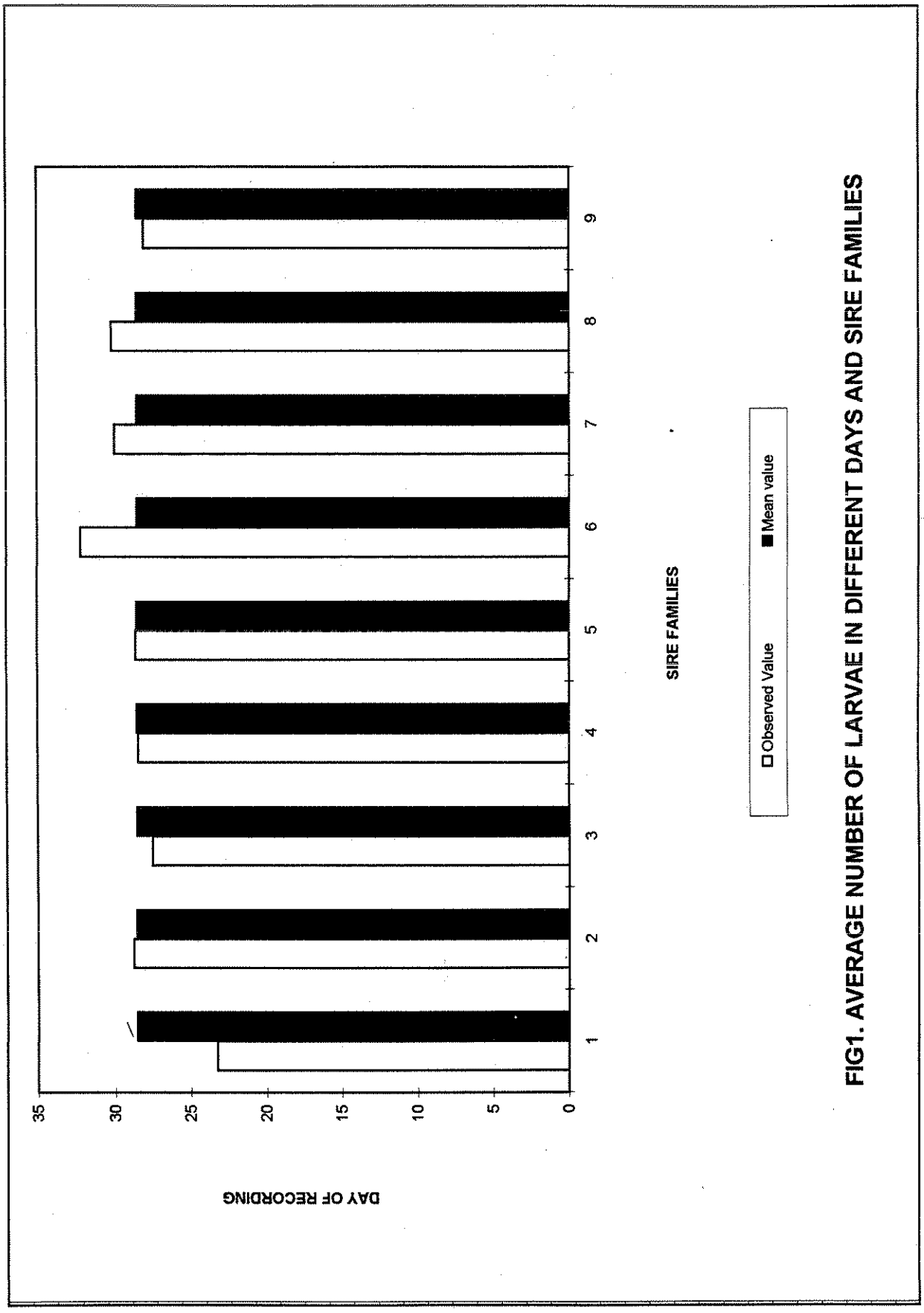

FIG1. AVERAGE NUMBER OF LARVAE IN DIFFERENT DAYS AND SIRE FAMILIES

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Laboratory culturing of flour beetles, *Tribolium* species.

Introduction

Culturing of insects under laboratory conditions is a useful and frequently necessary approach to investigations of a wide variety of problems associated with insects infesting stored products. The knowledge concerning biology and habitats of both insects and mites is important for any sound approach to storage problems. Chemical control methods need laboratory testing on the experimental insects under controlled conditions. The precise data obtained will be the base of field testing and ultimate formulation of control measures. Laboratory culture of insects provides the most convenient and meaningful method for obtaining such knowledges (Winks, 1983).

Tribolium species (Coleoptera : Tenebrionidae) are major insect pests of stored commodities of a wide variety and cosmopolitan in distribution (Sokoloff, 1972). The presence of these beetles in stored foods directly affects both quantity and quality of the commodity (Wilbur and Mills, 1985; Burkholder and Faustini, 1991). Adults produce quinones (Roth, 1943; Mondal, 1992) which are acutely toxic, allergenic and even carcinogenic to human beings (Ladisch *et al.*, 1967). Continuous trials with chemicals and fumigants are going on with *Tribolium* cultures under laboratory conditions for the search of newer as well as alternative control methods. Hence, the knowledge on proper culture of *Tribolium* spp. is important from the pest management point of view.

Culture media

The choice of culture medium for a particular species is based on several factors including the biological requirements of the species, the availability of constituents, the ease of preparation and sterilization and the consistency of the resulting preparation (Winks, 1983). The Slough Laboratory, Ministry of Agriculture, Fisheries and Food (MAFF), U.K. had compiled a list of culture media for many of the insects infesting stored products, based on the synthesis of biological data and culturing experience over many years. The culture media and rearing temperature for *Tribolium* species are given in Table 1. *Tribolium* beetles are easy to culture in large numbers and require no sophisticated equipment for maintenance. The culture medium is one of the main factors which controls the rate of development of *Tribolium* throughout ontogeny (Park and Frank, 1948; Sokoloff *et al.*, 1966).

However, differences in food constituents and their ratio together with temperature had also been reported for the optimum growth of cultures of different *Tribolium* species. *T. castaneum* develops better in a culture medium containing wholemeal flour and brewer's yeast in the ratio of 19:1 (Park and Frank, 1948) and at a temperature of 30°C (Mondal, 1984a; Parween, 1996). Up to 10% yeast can be used with wholemeal flour to ensure

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Table 1. The culture media of *Tribolium* species (after Winks, 1983)

Species	Food Media	Ratio	Rearing Temperature^{0}C
T. anaphe Hinton	Wheatfeed + Fishmeal + Yeast	8:4:1	25
T. brevicornis Lee	Wholemeal flour + Yeast	12:1	25
T. castaneum Herbst	Wholemeal flour + Yeast	12:1	25
T. confusum Duval	Wholemeal flour + Yeast	12:1	25
T. destructor Uyttenb	Wheatfeed + Fishmeal + Yeast	8:4:1	25
T. freemani Hinton	Wholemeal flour + Yeast	11:1	25
T. madens (Charp)	Wheatfeed + Fishmeal + Yeast	8:4:1	25

regular and continuous supply of *Tribolium*, and higher yeast level may reduce growth (Khan and Hasan, 1989; Hasan and Khan, 1991-1992); and agar does not permit proper growth of the culture (Hasan and Khan, 1988a). Rolled oats + wheatfeed + fishmeal + yeast in the ratio of 20:20:1:1 was reported as the culture medium for *T. brevicornis* by Hasan and Selman (1993). Better survival of the beetles is found on yeast enriched wheat flour than wheat germ, powdered rice and corn flour (Bergerson and Wool, 1987). Cerael flours e.g., barley, rice, corn and meal flours are not suitable as food of *Tribolium* (Sokoloff *et al.*, 1966; Mazid and Khan, 1987; Hasan and Khan, 1988b; Haque and Khan, 1988; Khan and Hasan, 1990a; Rashid *et al.*, 1993). The pulse flours also did not show significant growth of the beetles (Ali and Khan. 1986; Bhuiyan and Khan, 1986; Hasan, Momtaz and Khan, 1988; Hasan and Khan, 1988c; Khan and Hasan, 1988, 1990b,c; Nandi *et al.*, 1990). However, gram flour (Khan and Selman, 1981), millets (Islam and Khan, 1983) and mash flour (Rahman and Khan, 1988) may be used as alternative culture media for *Tribolium* species. Moreover, a temperature shock for a certain period may also hamper the growth of the culture (Hasan and Khan, 1989).

Homogenous mixture of the food constituents is the basic requirement for proper culturing of *Tribolium*. Flour and yeast should be passed through a 250 micrometer mesh sieve and then mixed thoroughly. The food should be sterilized before use, either by heating in an oven over 100^{o}C for a few hours or by cooling below -17.8^{o}C for one week. It is more convenient to heat sterilize the medium. Care should be taken that all the portions of the food medium must attain a temperature 80 to 100^{o}C for a required time. Normally it takes six to eight hours for warming up the whole medium in 2kg kilner jar. It is important that containers used for the heat sterilization of food medium must be well sealed before heating and allowed to cool at room temperature to prevent loss of moisture. The sterilized medium should not be used until at least 15 days after sterilization to stabilize moisture and to equilibrate with the environment (Khan, 1981; Mondal, 1984a). Keeping some crumpled filter papers allow wandering surface for the larvae and adults. The top of the culturing jars should be capped either with filter papers or muslin. Sokoloff (1993) reported Humpbacked flies (family Phoridae) in uncapped *Tribolium* culture.

Size of culture

The size of individual cultures, or culture units is usually determined by the factors like the number of insects required by the particular investigation, capacity of the incubator or insect room in terms of the total number of cultures maintained. In most species the

Table 2 Influence of different food media on growth and development of *Tribolium* spp.

Food	Species	Larval period (mean days±sd.)	Mature larval weight (mean mg±sd.)	Pupal weight (mean mg±sd.)	Pupal period (mean days±sd.)	Adult emergence (%)	Reference
Wholemeal flour + yeast (19:1)	*T. castaneum*	20.00±0.11	1.796±0.062	–	–	97.60	Mondal,1984a
	T. castaneum FSS II	20.69±0.59	3.61±0.24	3.95±0.38	6.49±0.11	92.95	Parween,1996
	CTC 12	20.64±1.09	3.16±0.12	3.97±0.51	6.54±0.31	98.70	
Wholemeal flour	*T. anaphe*	20.71±1.09	5.02±0.18	M 5.22±0.28 F 5.30±0.33	5.89±0.58	80.60	Haque & Khan,1993
	T. confusum	21.01±3.64	–	–	8.73±1.13	79.09	Hasan & Khan,1988a
Wholemeal flour + barley flour	*T. anaphe*	22.87±2.05	4.95±0.54	M 4.17±0.54 F 4.46±0.41	5.97±0.42	72.65	Haque & Khan,1993
Wholemeal flour + rice flour	*T. anaphe*	Range 24.10 - 24.62	5.03±0.51	M 4.28±0.35 F 4.83±0.34	Range 6.03 - 6.21	76.33	Haque & Khan,1993
Barley flour	*T. anaphe*	20.06±1.64	6.93±0.45	M 4.03±0.54 F 4.83±0.31	5.81±0.44	68.00	Haque & Khan,1993
	T. castaneum	19.32±2.05	–	–	5.31±0.49	75.50	Khan & Hasan,1990a
	T. confusum	19.63±1.79	2.32±0.29	–	5.46±0.53	69.50	Mazid & Khan,1987; Khan & Hasan,1990a
Rice flour	*T. anaphe*	27.91±0.87	–	–	6.72±0.53	59.33	Haque & Khan,1993
	T. confusum	24.05	2.30±0.25	–	–	–	Mazid & Khan,1987
Barley flour + Rice flour	*T. anaphe*	29.15±2.93	–	–	7.05±0.59	65.67	Haque & Khan,1993
Corn flour	*T. anaphe*	20.732.05±	3.58±0.36	5.98±0.64	3.37±0.27	59.67	Hasan & Khan,1988a
Wholemeal flour + corn flour	*T. anaphe*	20.34±1.73	4.37±0.41	5.97±0.49	4.43±0.23	79.67	Hasan & Khan,1988a

Table 2 contd.

Food	Species	Larval period (mean days±sd.)	Mature larval weight (mean mg±sd.)	Pupal weight (mean mg±sd.)	Pupal period (mean days±sd.)	Adult emergence (%)	Reference
Gram flour	*T. anaphe*	29.31±2.18	5.02±0.18	M 2.88±0.30 F 2.92±0.24	6.05±0.56	76.00	Khan & Hasan, 1990b
	T. confusum	40.72±5.50	–	–	10.42±0.50	38.26	Hasan Momtaz & Khan, 1988
Red gram flour	*T. anaphe*	27.16±2.06	2.76±0.26	M 2.32±0.23 F 2.59±0.27	5.97±0.51	71.50	Khan & Hasan, 1990a
	T. confusum	24.40±2.56	–	–	9.08±0.77	45.65	Hasan Momtaz & Khan. 1988
Pea flour	*T. anaphe*	24.36±1.95	2.83±0.19	M 2.71±0.20 F 2.74±0.27	5.81±0.48	54.00	Khan & Hasan, 1990a
	T. confusum	24.39±3.78	–	–	4.51±1.01	–	Bhuiyan & Khan, 1986
Red lentil flour	*T. confusum*	26.78±2.54	–	–	5.61±1.61	69.54	Bhuiyan & Khan, 1986
L. sativus flour	*T. castaneum*	36.37±3.17	2.05±0.49	–	6.84±0.57	55.00	Khan & Hasan, 1988
Millet flour							Islam & Khan, 1983
Panicum miliaceum	*T. confusum*	15.99±0.204	–	–	3.79±0.79	81.33	
P. typhoides	*T. confusum*	15.97±0.079	–	–	3.93±0.50	72.89	
Yeast level in wholemeal flour (%)	*T. anaphe*						Khan & Hasan, 1989; Hasan & Khan, 1991-1992.
0		21.67±1.67	4.42±0.31	4.57±0.47	6.05±0.36	71.00	
1		22.15±1.43	4.90±0.29	4.57±0.51	6.12±0.34	66.00	
2		21.97±1.56	4.95±0.27	4.61±0.38	6.10±0.39	69.00	
5		22.19±1.62	4.97±0.32	4.61±0.48	6.23±0.38	73.00	
10		22.17±1.74	5.05±0.037	4.71±0.53	6.15±0.41	77.00	
15		22.26±1.79	5.16±.042	4.80±0.44	6.32±0.47	72.00	
20		22.31±1.84	5.13±0.39	4.72±0.39	6.37±0.56	63.00	
25		22.47±1.81	5.18±0.036	4.76±0.42	6.58±0.51	62.00	
50		23.18±1.96	5.22±0.38	4.86±0.51	6.82±0.062	65.00	
100		25.73	3.36±0.41	3.99±0.49	6.97±0.79	35.00	

biological factors also influence the size of cultures. For example, *Tribolium* species are highly canniblastic under the condition of high density (Pajni and Virk, 1982) and are capable of delaying the developmental stage to avoid cannibalism in vulnerable pupal stage. At high density, the food medium is also conditioned by the quinones secreted by the beetles, which has an inhibitory effect on reproductive process (Mondal, 1983,1992). Moreover, overcrowding of the beetles increase the moisture content of the culture media. Molds develop on the culture medium and glue is formed by the flour particles in presence of condensed water droplets on the wall of the culture jars, even at the optimum moisture level (Lezcano and Sokoloff, 1993). Both of these conditions are fatal for the larvae and adults of *Tribolium*. On the otherhand, a dry culture medium forms a plug which detaches from the walls of the container, and often used as refuges by the surviving larvae, pupae and adults. Dried plugs sometimes used as food sources by the beetles. Dry plugs together with the faeces and decaying cadavars may turn to a black liquid in which the beetles may be drowned. The phorid flies are frequently found in the plugged culture media (Sokoloff, 1993).

Mite control in cultures

Mite populations develop frequently in *Tribolium* culture under conditions of high relative humidity. The following aspects are important with regard to mite control in the cultures:

(i) Work space should be clean and after use should be swabbed with ethyl alcohol or lightly dusted with sulphur (Winks, 1983). All glasswares and equipments used, should be clean and heat sterilize before and after use.

(ii) Culture should be rotated regularly by setting up new cultures and the old media should be destroyed.

(iii) It is better to use filter paper tops instead of quaze or muslin tops on the culture jars.

(iv) Cultures in the incubator should be placed on trays containing a small amount of paraffin oil (Winks, 1983).

(v) Mite infestations may be controlled in *Tribolium* cultures using chemicals like dicofol or sulphur.

Acarophenax tribolii is a common parasitic mite of different stored product beetles (Lepesme, 1944). Young females are found on the adults and their pupae (Evans *et al.*, 1961). Just before maturation these female acari leave the host and commence to feed on the eggs of the beetles. This acari is therefore very damaging to the laboratory cultures of *Tribolium*. Arnaud *et al.* (1996) gave a simple technique to eliminate this acari from *Tribolium* rears.

(i) Infested adults should be isolated in petridishes and placed in a dessicator containing 5% formol solution, for 10 hours. This treatment kills the acari present upon the beetles.

(ii) The adults are then transferred in fresh rearing medium (wheat flour and brewer's yeast in a ratio of 10:1) for 24 hours.

(iii) The eggs laid by these adults are then collected and passed through the above mentioned disinfection condition for six hours.

(iv) The eggs are then incubated in a fresh rearing medium at 30±3°C and 60±5% RH.

(v) All the materials used and the incubator also should be disinfected within 12 hours of the process.

A new culture may begin with these eggs.

Disease control in cultures

Tribolium cultures are very often attacked by pathogens which are capable of eliminating the whole culture in the laboratory. The most destructive organisms in this context are the protozoans, viz., *Farinocystis tribolii* Weiser, *Adelina tribolii* Bhatia and *Nosema whitei* Weiser (Sokoloff, 1974). The symptoms for both *F. tribolii* and *A. tribolii* are similar. infected cultures are poor in condition with a low yield of progeny, high adult mortality, blackened dead larvae and pupae, and a slightly dark appearance on the culture surface. Larvae of *Tribolium* infected with *N. whitei,* rarely pupated and all infected pupae died (Fisher and Sanborn, 1964). Black spots are seen at the centre of the *N. whitei*-infected larvae (Milner, 1970). The protozoan diseases may be confirmed by a simple larval squash in the water and examination for the spores under the microscope.

To prevent the attack of pathogens in the culture all the glasswares should be heat sterilized for at least one hour in an oven at 120°C. Similarly, sieves and other equipments should also be sterilized. Fresh filter papers should be used. Working areas of the laboratory should be maintained in a scrupulously clean condition. The infected culture is better to be destroyed. But if it is necessary to handle diseased cultures, e.g., to preserve a strain, unavailability of a new culture, etc., egg washing is needed to establish a disease free culture. Even a culture with low level of disease is also acceptable under such circumstances.

Preparing cultures

Collection of eggs : The eggs of *Tribolium* may be collected by sieving the culture through sieves having 500 and 250 micrometer apperture to seperate larval and adult, and the egg stages respectively (Khan and Selman, 1981a). Adults will be collected on the 500 micrometer sieve. Flour will pass through both the sieves. To remove bran and large flour particles extracted with eggs, the contents of the 250 micon sieve are transferred to a sheet of blotting paper and the eggs rolled off by inclining the sheet of blotting paper and gently tapping the underside of the sheet. The eggs are collected on a suitable tray while the bran and flour particles adhere to the fibres of the blotting paper. This process may be repeated, if necessary. Careful attention to this aspect of the technique simplifies subsequent egg washing. Moreover, black coarse papers may be used to collect as well as to count the eggs easily.

Egg washing : To establish a disease free culture, egg washing techniques (or egg sterilization) provides the most effective method. The following describes the egg washing \ method for T*ribolium* culture from materials infested with *F. tribolii*(Winks, 1983) :

a) Production of eggs

(i) Infected adults are placed on flour of a particle size less than 180 microns and held for 4 to 5 days following which they are removed by sieving through a 500 micrometer screen.

(ii) Eggs produced during the 4 to 5 day oviposition period are extracted from the flour by sieving the flour through a screen with a nominal mesh opening of 250 microns. Eggs are then retained on this mesh.

b) Washing of eggs

(i) The eggs collected are transferred to a small conical flask (50 to 100ml) and shaken vigorously with 0.1% benzalkonium chloride in distilled water. Following this the eggs

are allowed to settle to the bottom of the flask and the liquid decanted off. This washing process is repeated until the liquid is clear.

(ii) The washed eggs are transferred to a piece of muslin held on a filter funnel. They are then rinsed thoroughly with distilled water and finally with the aid of the jet from a wash bottle, confined within a small area of the muslin.

(iii) The piece of muslin is then placed on a filter paper to remove excess water and allowed to almost dry.

(iv) The area of the muslin containing the eggs is cut out with a pair of scissors and inverted on a new culture medium.

Throughout the washing process, scrupulous attention must be given to the hygiene and to heat sterilization of all the equipments used and the working area. It is believed that benzalkonium chloride does not kill the disease organisms but acts as a detergent to remove all the particles adhering to the egg surface.

Collection of adults : The adult beetles may be collected from the food medium by sieving the medium using a 500 micrometer sieve. Using a camel hair brush the beetles may easily be collected from the sieve.

Determination of sex : Some experimental techniques necessetate separation of sexes, e.g., studies of the genetics of resistance, tolerance of sexes to pesticides, measurement of reproductive capacity, etc. Sex may be differentiated easily from the external differences in adults or pupae. Sex differentiation is easy from the examination of the exogenital process of the female pupae (Halstead, 1963) than the genitilia of the adults.

Determination of larval instars : To have the larvae of different instars for experimental purposes newly hatched larvae are reared on a standard food medium of flour and yeast (19:1) at 30°C in an incubator. The second, third, fourth, fifth and sixth instar larvae may be obtained from the larval culture on 3rd, 6th, 9th, 12th and 16th days from the day of hatching respectively, while the newly hatched larvae may be used as first instar (Mondal, 1984b).

Providing a sequence of test material : To obtain large numbers of insect, approximately 200 adults should be added per 200g of the culture medium. The ratio of one beetle per gram of food is based on the upper realistic limit in natural populations of *Tribolium* to avoid overcrowding (Ogden, 1969). The beetles should be removed from the medium after one week. New cultures are set up each alternate week until the culture cycle is established.

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INSECTICIDE RESISTANCE IN *TRIBOLIUM CASTANEUM* HERBST AND *SITOPHILUS GRANARIUS* L.: COMPARING RESIDUAL FILM AND TOPICAL APPLICATION METHODS

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Introduction

Development of insecticide resistance in stored grain insect pests is a global problem (Champ and Dyte, 1976) and this has led to the failure of their effective control by these chemicals (Kenkel *et al.*,1994). *Tribolium* and *Sitophilus* species have also developed resistance to the insecticides commonly used in the protection of stored commodities (Subramanyam and Hagstrum, 1996). The current study shows the comparison of malathion resistance observed in resistant (Ph-1) and susceptible (FSS-II) strains of *T. castaneum* and of lindane in resistant (1022A) and susceptible strains of *S. granarius* by using residual film and topical application methods.

Materials and methods

The malathion resistant (Ph-1) and susceptible (FSS-II) strains of *T. castaneum* and lindane resistant (1022A) and susceptible strains of *S . granarius* were maintained at Department of Agricultural and Environmental Science, University of Newcastle upon Tyne, UK. The culture of both *T. castaneum* and *S. granarius* strains was kept in the incubator at 29±1°C and 70±5% relative humidity. The insects were reared in small Kilner jars (1/2 litre) covered with muslin cloth. Wholemeal flour supplemented with 5% brewer's yeast was used as the culture medium for *T. castaneum* and wheat grains with 13-15% moisture content were used for the rearing of *S. granarius*. Adult beetles of both sexes were used in the present study.

Technical malathion and lindane were provided by Hockley International CO. UK. Acetone (Analar) was purchased from BDH UK.

Stock solutions of test compounds (malathion for *T. castaneum* and lindane for *S. granarius*) in acetone were prepared and placed in refrigerator (3°C). Further serial dilutions were made within a week from these stock solutions, as required, to use in both residual film and topical application methods.

A. Residual film method for *T. castaneum* and *S. granarius*

The test method used with slight modification was based on the one described by Busvine (1971) in which he used residual film technique (contact film method). For this 1.0 ml of various prepared concentrations of each insecticide was spread on

petridishes (9 cm diameter) and dried. Four glass rings (5 cm diameter), inside coated with "FLUON GP1" for *S. granarius*, were placed in each petridish and 10 adult beetles were placed in each ring. Thus within each ring served as a replication. The treated petridishes along with beetles were left in the incubator and mortality was recorded after 24 hours.

B. Topical application method for *T. castaneum* and *S. granarius*

According to this method five to six concentrations of insecticides in acetone were applied at the rate of 0.5 µl/beetle with the help of a microapplicator and a microsyringe. Acetone only was used for control. The treated insects were kept in the petridishes at 29±1°C and 70±5% relative humidity for 24 hours. Thereafter, the mortality was recorded. Four replicates of 10 insects each were used for treatment.

The mortality data obtained by both methods were analysed by the probit method (Busvine, 1971).

A. Results for residual film method

The LD_{50} values of malathion, observed by residual film method, for *T. castaneum* (Ph-1 and FSS-II) and of lindane for *S. granarius* (1022A resistant and susceptible) are presented in Tables 1 and 2, and dose mortality responses are shown in Fig. 1 A and B, respectively.

B. Results for topical application method

The LD_{50} values, observed by topical application method, of malathion for *T. castaneum* (Ph-1 and FSS-II) and of lindane for *S. granarius* (1022A and susceptible) are given in Tables 2 and 3, and dose mortality responses are shown in Fig. C and D, respectively.

Discussion

Table 5 shows that the resistant ratio for Ph-1 strain of *T. castaneum* to malathion, compared with susceptible FSS-II strain, was 254 in case of residual film method but it was 237 when the compound was used in topical application bioassay. The similar figures of resistance ratios revealed that the insecticide proved to be relatively equally toxic to both strains of *T. castaneum* in both application methods. Table 5 also indicates that the resistance ratio for the 1022A strain of *S. granarius* to lindane, compared with susceptible strain, was 367 but it increased to 758 when the insecticide was used in topical application technique. With topical application of ^{14}C-lindane Singh and Kalra (1995) observed no significant difference between resistant and susceptible strains of *T. castaneum* in their ability to transfer the insecticide to the surface on which those were confined. Contrary to this Geoffrey *et al.* (1986)

reported that the adults of the resistant strain of *S. granarius* transferred significantly higher proportion of ^{14}C-lindane from their cuticle to the surface of confinement than the susceptible strain. So during present study, the higher resistance ratio for *S. granarius*, observed by topical application of lindane, might be due to more removal of insecticide from the cuticle by the resistant strain than the susceptible strain, however, in case of residual film method the insects remained in regular contact with the insecticide residues.

The results of both techniques led to similar conclusion about the relative susceptibility of the strains of *T. castaneum and S. granarius* to malathion and lindane, respectively. For malathion, both residual and topical tests showed that FSS-II strain of *T. castaneum* was highly susceptible as compared to Ph-1 and for lindane susceptible strain of *S. granarius* proved to be highly susceptible when compared with 1022A by both residual and topical application methods.

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Table 1. Toxicity of malathion to strains of *T. castaneum* by residual film method

Strain	LD_{50} ng/cm^2	95% confidence limit lower	Upper	Slope
Ph-1	1372.7	1051.3	1684.5	1.98 ±0.1
FSS-II	5.4	3.38	7.3	2.87 ± 0.15

Table 2. Toxicity of lindane to strains of *S. granarius* by residual film method

Strain	LD_{50} ng/cm^2	95% confidence limit lower	Upper	Slope
S. granarius (1022A)	1675.6	1109.1	2145.1	2.39 ± 0.3
S. granarius (susceptible)	4.57	3.91	5.19	2.54 ± 0.4

Table 3. Toxicity of malathion to strains of *T. castaneum* by topical application method

Strain	LD_{50} ng/beetle	95% confidence limit lower	Upper	Slope
Ph-1	6401	5299	7692	2.76 ±0.32
FSS-II	27	24	30	3.92 ± 0.51

Table 4. Toxicity of lindane to strains of *S granarius* by topical application method

Strain	LD_{50} ng/beetle	95% confidence limit lower	Upper	Slope
S. granarius (1022A)	5310	2659	10540	1.35 ± 0.18
S. granarius (susceptible)	7	6	9	2.23 ± 0.28

Table 5. Resistance ratios for resistant strains relative to susceptible strains of *T. castaneum* and *S. granarius* by residual film and topical application methods

Species	Insecticide	*Resistance ratio(RR)	
		Residual	Topical
T. castaneum	malathion	254	237
S. granarius	lindane	367	758

*Resistance ratio (RR) $=LD_{50}$ of resistant strain/LD_{50} of susceptible strain

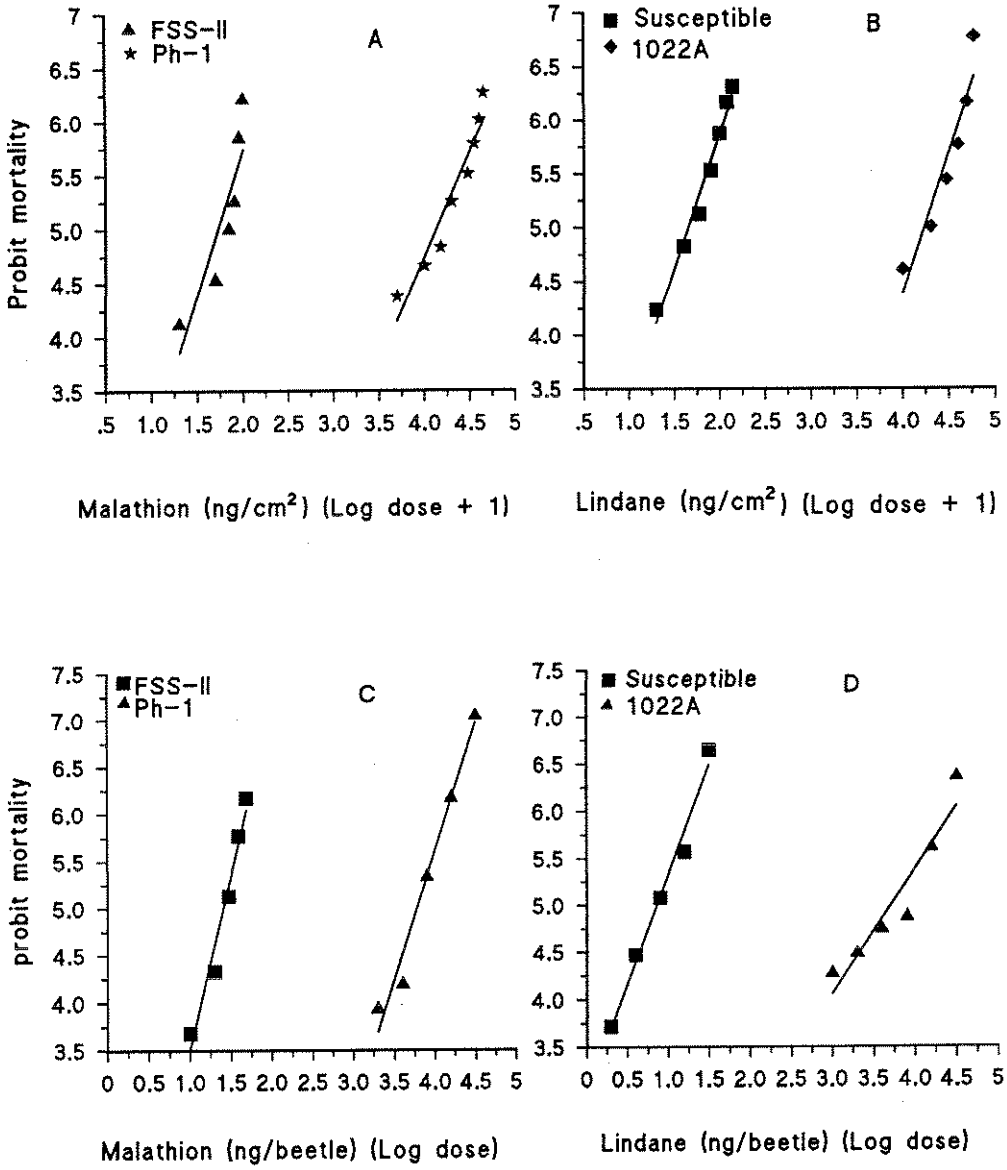

Fig 1 Dose mortality response of *Tribolium castaneum* strains to malathion and of *Sitophilus granarius* to lindane by residual film (A and B, respectively) and topical application (C and D, respectively) methods.

Notes - Research, Teaching and Technical

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*YIELD OF TRIBOLIUM CASTANEUM (HERBST) FROM MEASURED AMOUNTS OF FLOUR.

The purpose of this experiment was to determine how many batches of adult Tribolium castaneum can be obtained from known measured amounts of flour. This type of information is difficult to come by, because investigators' techniques are not standardized and they are quite variable. In the present study we have chosen to start the experiment with 150 first instar larvae and 5 grams of Tribolium flour medium in each of 10 vials. At the end of four weeks we remove the adults, weigh them en masse and discard them. This is referred as Trial 1. In the successive trials we repeat the experiment by introducing 150 first instar larvae into the same flour and allow these to become adults and weigh them. This is repeated as many times as we obtain live adults. When the vials no longer produced adults, the vials were observed for as long as three months to make sure that the larvae introduced in the last trial had failed to reach the adult stage. The results are so striking, that it has not been necessary to apply any special statistical methods to make obvious conclusions. The raw data for those who are interested in further analyses are given in the appendix at the end of the paper.

MATERIALS AND METHODS

The experiment was carried out in an incubator maintained at 29 C. and 70% R.H. We introduced into each of 10 vials 5g of standard medium (whole wheat flour plus brewer's yeast in a ratio of 19:1 by weight). In the first trial we introduced 150 first instar larvae into each vial. Four weeks later the adults were removed from their vials, counted, weighed en masse, and discarded. The used flour was returned to its respective vial. In the second, third and fourth trial each vial was re-seeded with another batch of 150 first instar larvae, incubated, and if adults were present they were again mass-weighed. There were no problems in the second trial. In the third trial, at the end of four weeks, there were adults (and no remaining larvae) in five replicates and these were weighed and discarded. In the remaining five vials there were no adults, but there were larvae or pupae These vials were returned to the incubator for another period of four weeks. Only two of these vials produced adults: Vial 2 produced 5 adults weighing 0.008 g and vial 6 28 adults weighing 0.058 g. Only one of the three remaining vials contained live larvae (and these weighed 0.012 g). The remaining larvae, if any, were dead. The vials of the third trial were then re-seeded with 150 first instar larvae for a fourth trial. These vials were examined 25 days later, and

re-examined 30 and 51 days later. There were no live larvae or adults in vials 1, 2, 4, 5, 7, 8, 9 and 10. In vial 3, one dead ault and one dead pupa were found. In vial 6 there were 3 dead larvae which had developed to about the third instar.

ANALYSIS OF DATA

1) Number of larvae surviving to the adult stage

First trial. Out of 1500 larvae introduced, 1302 survived to become adults, with an average survival value of 86.8%. The number of adults obtained is shown in Appendix Table 1. The minimum number of adults was 118 and the maximum 141 adults. The average adults per vial was 130.2+6.43.

Second trial. As shown in Table 1, Trial 2bt, out of 1500 larvae, 879 (or 58.6%) survived to the adult stage. The range of values was from a minimum of 78 to a maximum of 99. The mean and standard deviation was 87.9+6.40

Third Trial. As noted above, two main groups are observed at this time: 5 replicates in which there were adults at the end of four weeks, and 5 replicates in which the adults had not appeared at the end of four weeks, necessitating a continuance of these vials for a period of time. Only two of these vials showed adult beetles (vials 2 and 6 in Appendix Table 3b). In terms of survival, the total number of adults surviving in the first five vials was 265, and the percent taking 750 as the total larvae for the five vials is 35.33%. An additional 33 survived to the adult stage in two of the remaining five vials bringing the total to 298 adults in 7 vials (298/1050=28.38). If the 1500 larvae in the ten vials is considered, the percent survival is 19.87%

Fourth Trial. The survival of larvae to the adult stage in the fourth and last trial was 0%. There were no adults although there were live larvae visible at the end of one, two or three 4-week intervals, and the experiment was terminated.

2. Weight of surviving adults

Trial\1. As shown in Table 1, the total weight of surviving adult beetles ranges from 1.908 to 2.690 grams with a mean mass weight of 2.507+2.29 E-02. The average weight of beetles, disregarding sex, is 1.925.

Trial 2. The total biomass of beetles per vial ranges from .164-.222g with a mean of 1.937g/vial. The weight per beetle ranges from 2.047 to 2.524mg, with an average of 2.204mg.

Trial 3. For the five vials where 265 adults were obtained the total weight of the beetles adds up to 0.463g or an average weight of 1.747 mg per beetle. Incorporating the weight of adults found at the end of the second month, the total weight of 298 adults becomes 0.526g and the mean weight per individual is 1.766mg.

Trial 4. No larvae survived to the adult stage in this trial.

Weight of the total biomass of beetles in all three trials. There were 2479 adults produced in all three trials with a total weight of 4.973g. the average weight per individual is 2.047mg

3. Weight of the used flour at the end of Trial 4.
The weight of the flour introduced initially into each vial was 5g (50g for the ten vials. The weight of the flour after the fourth trial ranges as shown in Table 5. The weight ranges from 1.903-3.018g. The average of flour is 2.224+.3847g. Therefore there has been a loss of 2.776g/vial in the weight of the flour.

Conclusion.

The 5 grams of flour in each of the ten replicates was able to produce an average of 130.2 adults in Trial 1. Reuse of the used flour to repeat the experiment produced an average of about 88 adults. The variance in the ten replicates in these two trials is about the same. In Trial 3 half of the replicates had adults within four weeks, while in the other half of the replicates adults were found only in three replicates. The variance of survival in Trial 3a is about 20 times greater than in Trials 1 and 2. In Trial 3b the number of beetles is small, but the variance appears to be greater than in Trials 1 and 2.
An examination of the biomass data shows that the greatest biomass was produced in Trial 1. Trial 2 had a reduction of biomass of about 25%. The biomass produced in Trials 3a and 3b taken together is only about one fourth of the value obtained in Trial 2. Trial 4 shows that the medium is no longer of any nutritional value to support the development of the larvae to the pupa of the adult stage.

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APPENDIX

YIELD OF TRIBOLIUM ADULTS IN MEASURED AMOUNTS OF MEDIUM

Trial 1.

Vial #	# Beetles	Beetle Weight (g)
1	134	0.264
2	118	0.190
3	129	0.250
4	130	0.260
5	127	0.247
6	130	0.252
7	141	0.269
8	126	0.246
9	129	0.262
10	138	0.267
Total	1302	2.507

Trial 2

1	93	0.198
2	89	0.201
3	84	0.185
4	82	0.207
5	95	0.213
6	89	0.213
7	84	0.172
8	99	0.222
9	78	0.164
10	86	0.177
Total	879	1.937

Trial 3a

1	41	0.073
2	0A, SL	---
3	0A, SL	---
4	41 (2L)	0.090
5	70 (2L)	0.115
6	0 A	---
7	60	0.098
8	53	0.087
9	0 A, SL	---
10	0 A, SL	---
Total	265	0.463

Trial 3b

1	See 3a	
2	5(12 d, 2lL)	0.008
3	(65 d, 3lL)	0 A
4	See 3a	
5	See 3a	
6	28 A (1L)	0.058
7	See 3a	
8	See 3a	
9	(28 dL)	
10	13 lL	(0A, .012 lL)

Symbols: A: adults; L=larvae; lL = live larvae; d = dead.

Total for 3a and 3b: 298 0.541

Trial 4. No adults present

Grand total (Trials 1-4): 2479 4.373g

Table 5

Vial #	Weight of medium (g)
1	2.006
2	2.283
3	2.209
4	2.045
5	1.939
6	1.912
7	2.122
8	1.903
9	2.796
10	3.018
Total	22.236

Descriptive statistics

	N	Minimum	Maximum	Mean	S. D.	Variance
Trial 1bt	10	118	141	130.2	6.4256	41.289
Trial 2bt	10	78	99	87.9	6.4023	40.989
Trial 3bt	10	0	70	26.5	29.15	849.833
Trial 4bt	10	0	28	3.3	8.8198	77.789
Mass 1	10	.1900	.2690	.2507	2.29E-02	5.238E-04
Mass 2	10	.1640	.2220	.1937	1.87E-02	3.498E-04
Mass 3	10	.0000	.1150	3.75E02	4.75E-02	2.252E-03
Mass 4	10	.0000	.0580	7.80E03	1.81E-02	3.293E-04

Explanation of symbols:
bt = number of beetles in Trials 1, 2, 3 and 3a.
Mass = total weight of the beetles in Trials 1-3a.
There were no survivors to the adult stage in Trial 4.

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Availability of the compulsory pupation in order to estimate genetic parameters in Tribolium freemani.

INTRODUCTION

T. freemani rediscovered in Japan has a few ecological characteristics distinct from T. castaneum and T. confusum used extensively in the world (Nakakita, 1983). Under ordinary feeding circumstances T. freemani has a strong tendency to pupate sporadically and to survive as mature larvae. Nakakita has explained this phenomenon as the crowding effect. But T. freemani is almost double-sized, cannot fly and acts slowly as compared with T. castaneum. These characters are useful to handle insects easily with a vacuum tweezers and are favorable to the breeding experiments which necessitate data in large quantities.

First step of this study was to confirm whether uniform pupae can be collected or not in large quantities using the compulsory pupation method to set mature larvae in fasting and individual separation condition. Subsequent development from pupation to adult emergence and the reproduction ability should be checked not to cause disturbance in practicing experiments. The object of this study was to confirm whether proper estimates of genetic parameters can be gained or not by using the compulsory pupation method likewise in the case of T. castaneum.

MATERIALS AND METHODS

Several T. freemani stocks maintained by National Food Research Institute of Japan were mixed to increase genetic variability and used in this study. The medium was wheat flour supplemented with dried yeast at a ratio of 19:1 by weight which realizes the fastest larval development (Imura, 1991). Adult males and females after emergence were maintained separately on this medium in the plastic containers (100 mm i.d. x 55 mm ht.) One day mating (1 male:10 females) was carried out in the tissue culture dish (35 mm x 10 mm) with a small quantity feed. After mating only females were transfered to plastic containers to gain good developed larvae. All insects were kept in an incubator at 30 $\pm$ 1 $^{\circ}$ C and 65 $\pm$ 10 % r.h.

The compulsory pupation was practised by putting the mature larvae into wells of tissue culture plate (12 $\times$ 8: 96-well) individually 1 or 2 days after the first pupation was found in the plastic containers. And adult emergence after pupation was practised in the same tissue culture plate. Sexing of pupae and body weight measuring of each life stage in the plate were practised individually at the 0.1 mg accuracy level. To estimate heritability ordinary hierarchical analysis of variance was practised. All larvae used for this analysis were kept in the tissue culture dish at ad libitum feeding.

RESULTS AND DISCUSSION

The body weights of each developmental stage and developmental days in the case of the compulsory pupation use are shown in Table 1. This adult weight was a little heavier than that presented by Nakakita and Imura. This suggests that use of the compulsory pupation method is a appropriate procedure to gain many pupae and adults in experiments using T. freemani. Developmental measurements are very variable according to feeding system and the discrimination of mature or immature larvae is very difficult. In this experiment the failure gaining pupae from larvae was under 10 percent and that gaining adult from pupae was under 5 percent. Adopting one day oviposition to prevent immature larvae mixture will be desired to gain pupae at more success percent.

The large difference of developmental weights in Table 1 and Table 2 reflects the influence of containers size which experimental larvae were fed. The tissue culture dish used to make data of Table 2 is too much small to rear larvae in spite of ad libitum feeding. But the restricted feeding experiment in tissue culture dish shows next figures: larval weight:3.96 $\pm$ 0.63, pupal weight:3.49 $\pm$ 0.54, adult weight:3.00 $\pm$ 0.51 (unpublished).These findings suggest the possibility of two directional selection experiments using T.freemani.

Heritabilty estimates of pupal and adult weight of Table 3 were a little bigger than those of T. castaneum in the case of estimation using sire component (Sokoloff, 1977). But estimates using dam component and sire + dam component were clear over-estimate. This suggests the big presence of maternal effect strongly. Maternal effect is likely to be included in the trait of pupal weight much more than in the trait of emergent adult weight as shown in heritability estimates. Considering maternal effect, heritability estimation using sire component has validity. Selection experiments will be expected to be practised by means of the compulsory pupation method using T. freemani.

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Table 1. Body weight change by use of compulsory pupation of mature larvae in T. freemani.

	sample no.	larval wt.	pupation days	pupal wt.	emergent days	adult wt.
male	134	7.57±0.57	5.5±0.9	6.43±0.52	6.1±0.4	5.54±0.42
female	112	7.73±0.64	5.4±0.9	6.60±0.51	6.1±0.4	5.69±0.42

Table 2. Vital statistics of samples used to hierarchical analysis of variance. (sire no. :23, dam no. :159)

	pupal wt.	adult wt.
sample size	2,039	2,039
minimam wt.	3.0	2.7
maximam wt.	6.9	6.1
mean ± S. D.	5.04±0.62	4.48±0.52
C. V.	0.12	0.12

Table 3. Heritability estimates of pupal and adult weight.

	pupal wt.	adult wt.
h^2_S	0.466	0.411
h^2_D	1.607	1.455
h^2_{S+D}	1.036	0.933

Notes - Research, Teaching and Technical

COMPARISON OF LINEAR ANALYSIS AND COMBINING ABILITY ANALYSIS FOR VARIOUS CROSSES DESIGNS

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SUMMARY

Five lines of *Tribolium castaneum* (H, L, C, PY and R) were crossed in a full diallel and tested with a control line. The data of pupa weight and offspring number were analysed using two statistical models, combining ability model and mixed linear model. The results showed that the heterosis of lines which were formed by selecting was obvious. The reproduction capacity of populations whose inbreeding were high was relatively poor. Crossbreeding effects of specialized lines were better than those of inbreeding lines. Hot stress could produce negative effect to growth traits and reproduction traits. In order to increase whole economic benefit, crossbreeding could be used to improve the resistance to hot stress. For complete diallel crosses design, the correlation coefficient of crossbreeding effects which were estimated by two models was significance. SCA effect which was estimated by mixed linear model had the best correlation with the heterosis rate (Pupa Weight R=0.93**; Offspring number R=0.84**). For incomplete diallel crosses design, mixed linear model was better than combining ability model. When conditions of the experiment were limited, the reciprocal circulant plans would be a better choice.

Key words: crossbreeding, crosses design, crossbreeding effects, combining ability, linear model

INTRODUCTION

Crossbreeding is a widely used system for production of many kinds of animals, because crossbred individuals perform better than the average of their parents. It also be called "heterosis".But the heteosis does not always exist between any breeds or lines. It is important to estimate (or prediction) effects of the crossbreeding experiment. Data from crossbreeding experiments are commonly analysed by ordinary least square (OLS), fixed-procedures (Robison 1981;Koch *et al.*1985). Only recently, the relationship structure of animals within and between groups has been considered, then generalized least square (GLS) procedures is to be used (Hagger 1989; Pedersen 1989). To date, there are\some authors (Elzo *et al.* 1985; Komender 1988,1989) have considered mixed-model methodology as a tool for estimating crossbreeding parameters. A fixed model and 4 mixed models are compared using data from a diallel crossbreeding experiment with pigs by Komender (1988,1989). Results demonstrate that the animal model accounting for all additive genetic relationships could reduce the true standard errors of the estimates of crossbreeding parameters, and may remove biases caused by confounding of certain animals and crossbreeding groups and by selection.

It is the purpose of this contribution to compare mixed linear model and combining ability model for various crosses designs which include complete diallel crosses, incomplete diallel crosses and

reciprocal circulant plans. In addition, the paper also discusses the hot stress effects of growth traits and reproduction traits of *Tribolium castaneum*.

MATERIALS AND METHODS

In this experiment, five lines of *Tribolium castaneum* (H, L, C, PY and R) have been selecting for several generation according to the following criteria:

line H: high pupa weight

line L: low pupa weight

line C: unselecting

line R: hot stress resist

line PY: unselcting , small size

After one generation without selection, the five lines were crossed with each other producing 25 groups according to a complete diallel scheme. The data of pupa weight and offspring number were analysed by combining ability model and mixed linear model according to various crosses designs (complete diallel crosses, incomplete diallel crosses and reciorocal circulant crosses).

Combining ability model. Model I of Griffing was chosen to calculate general combining ability and specific combining ability. This model can be described by the equation:

$y_{ij} = \mu + g_i + g_j + s_{ij} + e$

where: y_{ij} =mean of the group resulting from crossing line *i* with *j*; μ=overall mean of all population; g_i , g_j =general combining ability of line *i* or *j*; s_{ij}=specific combining ability of line *i* and line *j*; e=random error.

Mixed linear model. Crossbreeding effects of the linear model were also taken as fixed, because the crossbreeding groups were considered fixed,.The model in matrix notation is

$y = Sp + X\beta + Z_1 a + Z_2 b + e$

where: y=vector of observations; p=vector of crossbreeding effects; S=incidence matrix of p; β=vector of fixed effects other than p; X=incidence matrix of β; a=vector of random genetic effects with mean vector zero and $var(a)=A\sigma_a^2$; Z_1= incidence matrix of a; b=vector of random effects other than a with mean vector zero and $var(b)=I\sigma_b^2$; Z_2= incidence matrix of b; e=random error with mean vector zero and $var(e)= I\sigma_e^2$. Data analysis were carried out with multiple traits derivative-free REML (MTDFREML) package of K.Meyer.

RESULTS AND DISCUSSION

Combinging ability analysis. In this paper ,combining ability effects were estimated and tested in complete diallel crosses design by Model I of Griffing only. Estimates of general combining ability (GCA) and specific combining ability (SCA) are given in Table 1 and Table 2 respectively. The genetic basis of crossbreeding effects can be divided into two major components: additive and nonadditive effects. GCA corresponds to additive effect, so it can be improved by selecting. Then for the trait of pupa weight, the GCA of every line was significance . But for the trait of offspring number, the differences of H, L and C lines were not significance. Compared with PY line, the reproduction capacity of four lines was relatively poor because of higher inbreeding (inbreeding coefficient:

0.14 ~ 0.17). The SCA corresponds to nonadditive effect of crossbreeding. It is true source of heterosis. Both traits of pupa weight and offspring number, the best and the worst groups of SCA were corresponding to those of heterosis which are given in Table 3.

Table 1. Estimates of GCA and significance test

	G_H	G_L	G_C	G_P	G_R
pupa weight	21.62**	-6.63**	16.44**	-16.17**	-15.24**
offspring number	-0.96	-0.21	-0.67	5.76**	-3.92**

*: P<0.05 **: P<0.01

Table 2. Estimates of SCA and significance test

	S_{HL}	S_{HC}	S_{HP}	S_{HR}	S_{LC}	S_{LP}	S_{LR}	S_{CP}	S_{CR}	S_{PR}
pupa weight	-2.35	4.68**	-0.29	-16.3**	-4.1**	6 **	-3.86**	9.1**	-2.53*	-4.79**
offspring number	-0.36	-1.88	4.5**	0.63	1.83	-0.3	-0.03	1.44	0.05	-4.14**

*: P<0.05 **: P<0.01

Table 3. *t* test of heterosis

	HL	HC	HP	HR	LC	LP	LR	CP	CR	PR
pupa weight	-4.69*	0.12	4.72**	-13.2**	-1.25	10.9**	-7.9**	14**	-4.9**	1.04
offspring number	50.6**	1.08	57.1**	-11.5	47**	12.69	-12.86	19.9*	-17.9	-38**

*: P<0.05 **: P<0.01

Correlation analysis of heteosis and SCA effects estimated by different methods. An important objective of crossbreeding experiment is to obtain higher heterosis. Consequently, for various crosses designs, effects of combining ability analysis and linear analysis are compared with heterosis rate. Correlation coefficient and significance test are given in Table 4. For complete diallel crosses design, the correlation coefficient of crossbreeding effects which were estimated by two models was significance. SCA effect which was estimated by mixed linear model had the best correlation with the heterosis rate. For incomplete diallel crosses design, mixed linear model was better than combining ability model. The reciprocal circulant plans would be a better choice when conditions of the experiment were limited.

Table 4. Correlation coefficient of heterosis and SCA effects estimated by different methods.

heterosis	A	B	C	D	E	F	G
pupa weight	0.98**	0.42	0.49	0.69*	0.72*	0.55	0.25
offspring number	0.84**	0.75*	0.66*	0.81**	0.51	0.55	0.32

*: $P<0.05$ **: $P<0.01$

[A]Using mixed linear model to analyse complete diallel crosses $\{P^2\}$

[B]Using mixed linear model to analyse incomplete diallel crosses $\{\frac{1}{2}P(P+1)\}$

[C]Using mixed linear model to analyse incomplete diallel crosses $\{\frac{1}{2}P(P-1)\}$

[D]Using mixed linear model to analyse reciprocal circulant crosses

[E]Using combining ability model to analyse complete diallel crosses $\{P^2\}$

[F]Using combining ability model to analyse incomplete diallel crosses $\{\frac{1}{2}P(P+1)\}$

[G]Using combining ability model to analyse incomplete diallel crosses $\{\frac{1}{2}P(P-1)\}$

Hot stress. Hot stress could produce negative effect to growth traits and reproduction traits. However, crossbreeding can give rise to economic gains if production traits put reduced emphasis and if nonproduction traits, such as disease resistance and stress resistance, play an important role in the breeding objective.

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INDEX OF RESEARCH, TEACHING AND TECHNICAL NOTES

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NOTE: An asterisk denotes the individual who, as far as known, has worked or is working on Coleoptera. The plus sign (+) before the geographical locality indicates there was no current contribution. Since the information was obtained from previous issues of TIB, there is no guarantee that the information is accurate.

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