TRIBOLIUM INFORMATION BULLETIN

Number 26

July, 1986

Bibliography

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VOLUME 26

1986

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NOTE

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ACKNOWLEDGMENTS

The editors are indebted to ALEXANDRA SOKOLOFF and ELAINE SOKOLOFF for assistance in the preparation and distribution of TIB 26

STOCK LISTS

NOTE: The present listing of laboratories is further reduced from that given in TIB-25. Some investigators are no longer doing any research on Tribolium, and we wish them well in their new avenues of research, with whatever organism their interests meet their needs. The editors will be contacting the principal investigators of the laboratories listed in the near future to find out which of their stocks are still extant.

STOCK LISTS

BERKELEY, CALIFORNIA
UNIVERSITY OF CALIFORNIA
DONNER LABORATORY AND LAWRENCE RADIATION LABORATORY

Tribolium confusum

1. "+" - a wild type strain derived from Genetics Department, University of California, Berkeley.

2. Black - an autosomal semi-dominant body color mutant. From 1.

3. Miniature - an autosomal recessive body size mutant. From 1.

4. Short elytra - an autosomal dominant elytron-size mutant. Low viability in adults, indicating a recessive lethal gene.

5. Blistered elytra - an autosomal recessive mutant. Low viability.

Tribolium brevicornis.

Wild type derived from Genetics Department, University of California, Berkeley.

(Ed.).

BRIDGEPORT, CONNECTICUT
UNIVERSITY OF BRIDGEPORT
DEPARTMENT OF BIOLOGY

Tribolium confusum

Wild type strains derived from Dr. Fraenkel's laboratory at the University of Illinois.

(Ed.).

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

Tribolium castaneum

Unsaturated fatty acid corn oil sensitive (cos)

Tribolium confusum

Chicago wild
black

Tribolium madens

Tribolium brevicornis

All stocks derived from stocks at University of Rhode Island.

(Ed.).

Stock Lists

CARBONDALE, ILLINOIS 62901
SOUTHERN ILLINOIS UNIVERSITY AT CARBONDALE
DEPARTMENT OF ZOOLOGY

Tribolium castaneum

I. Wild type strains

1. Purdue + Foundation

II. Mutant strains

1. antennapedia (ap)
2. antennapedia, black (ap, b)
3. Chicago black (b) via San Bernardino
4. weird (wd) via San Bernardino

D.C. Englert

CARLISLE, PENNSYLVANIA
DICKINSON COLLEGE
DEPARTMENT OF BIOLOGY

I. Wild type strains (T. confusum)

1. Six strains started from females captured in a feed bin in New York City, 1955.

2. Three strains, one each from T. Park, Chicago; J. Stanley, Montreal; S. Smith, Sault Ste Marie, Canada.

3. One strain consisting of several above strains mixed together about three years ago.

4. One strain started with individuals taken from (1) above, which has been freed of eye mutations.

NOTE: Some of the wild strains listed in (1) and (2) are known to be carrying pearl-like mutations.

II. Mutant (T. confusum).

1. Black -Sault Ste Marie (1956)
2. Ebony - Chicago (1957)
3. Eyespot - sex-linked - from a I.1 strain above (1959)
4. Rough - from strain II.1 above (1957)
5. Split - from a wild strain in I.1 above (1956)
6. Striped - sex linked - from II.1 above (1957)
7. One strain each of Striped/black and split/black

Oryzaephilus surinamensis- from insects found in NYC, 1955.

Dan McDonald

Stock Lists

CHARLOTTESVILLE, VIRGINIA
UNIVERSITY OF VIRGINIA
DEPARTMENT OF BIOLOGY

Tribolium castaneum

I. Wild type strains

1. Chicago	University of Chicago
2. Purdue University Foundation	via Stony Brook
3. Synthetic	San Bernardino

II. Mutant strains

1. McGill black	University of Chicago

(Ed.).

CHICAGO, ILLINOIS
UNIVERSITY OF CHICAGO
DEPARTMENT OF BIOLOGY

I. Wild type strains

A. Tribolium castaneum

1. "Chicago" (originally from Thomas Park)
2. Brazil (also known as cI)--(originally from Rio de Janeiro)
3. cIVa--an inbred strain (derived from Chicago)

B. Tribolium confusum

1. "Chicago" (originally from Thomas Park)
2. bI an inbred strain derived from the Chicago strain)
3. bII (same)
4. bIII (same)
5. bIV (same)

C. Tribolium madens

D. Latheticus oryzae

(Ed.)

Stock Lists

CHICAGO, ILLINOIS
UNIVERSITY OF ILLINOIS AT CHICAGO CIRCLE
DEPARTMENT OF BIOLOGICAL SCIENCES

I. Wild type strains

A. Oryzaephilus surinamensis

B. Tribolium castaneum

1. "Chicago" (originally from Thomas Park)
2. "Brazil" (also known as cI) originally from Rio de Janeiro)
3. cIVa (an inbred strain derived from "Chicago"

C. 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")

D. B. Mertz

CORAL GABLES, FLORIDA
UNIVERSITY OF MIAMI
DEPARTMENT OF BIOLOGY

I. wild type strains

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

II. Mutant

T. confusum - ebony--Sokoloff	Sokoloff
T. castaneum - jet - from Chicago wild	
T. cataneum - Chicago black-- Sokoloff	
T. castaneum - sooty (Sokoloff)	
T. castaneum - dark sooty (Sokoloff)	
T. castaneum - Charcoal--Sokoloff	
T. castaneum - tawny/pearl--Sokoloff	

Earl R. Rich

Stock Lists

CORVALLIS, OREGON
OREGON STATE UNIVERSITY
DEPARTMENT OF ZOOLOGY

I. Wild type strains

A. Tribolium castaneum
1. Oregon (synthetic)

B. Tribolium confusum
1. Oregon synthetic

II. Mutant strains

A. Tribolium castaneum

1. aa, mc, j
2. ap^{D}, s
3. apt, b
4. b,mc,p
5. bb
6. Be
7. dve,pd
8. Fta
9. h^{c}
10. mc^{c}, s
11. nd, s
12. p, lod
13. Rd, s
14. sa-2, +/s
15. Sa-2, s
16. ser, py, r
17. Spa
18. wd, s

Tribolium confusum
1. b^{u}
2. b,spl
3. ble^{u}
4. dep
5. dj
6. e^{c}
7. msg^{AS}
8. r^{u}
9. thu
10. thu^{u}

Peter S. Dawson

Stock Lists

DENTON, TEXAS
TEXAS WOMAN'S UNIVERSITY
DEPARTMENT OF BIOLOGY

I. Wild type strains and origin

A. Tribolium castaneum (Brazil cI)
B. Tribolium confusum (Chicago Standard)

(Ed.).

FLUSHING, NEW YORK 11367
QUEENS COLLEGE OF THE CITY UNIVERSITY OF NEW YORK
DEPARTMENT OF BIOLOGY

Tribolium castaneum wild type, Purdue University

(Ed.).

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).

A.E. Bell.

Stock Lists

LAURINGBURG, NORTH CAROLINA
ST. ANDREWS COLLEGE

Tribolium confusum-- Wild type stock infected with *Nosema whitei*

(Ed.).

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.).

MADISON, WISCONSIN
UNIVERSITY OF WISCONSIN

Xyleborus ferrugineus

I. Wild type strain WIS-1 from Costa Rica

II. "Germfree" strain WIS-2, derived from WIS-1.

NOTE: This insect in the wild exists in obligatory symbiosis with filamentous fungi, yeasts and bacteria. The insect reproduces by arrhenotokous parthenogenesis with unfertilized (haploid n=7) eggs yielding male progeny, and fertilized (diploid, n=14) eggs yielding female progeny. Females can be kept alive for 9-12 months and will retain fertility over most of their life. Thus many experiments can be conducted with a given individual. The insect only decodes its larval genome into the phenotype if given a non-7-sterol. Imaginal phenotypic characteristics are decoded onlly when a dietary 7-sterol is provided to the larva. No other insects are known to provide this combination of attributes to researchers in the areas of cell determination versus differentiation, and other aspects of organismal development.

A new stock line can be started from a single virgin female by allowing her to produce male progeny which whe will tend until they are adults, then will mate with a son, and then will produce mostly diploid female progeny which can be used to continue the created line.

(Reproduced from an earlier issue of TIB, 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

1. au, lod, p--aureate, light ocular diaphragm, pearl (III,III,II) from San Bernardino, 1981
2. sa, c--short antenna, chestnut (VII, VII) "
3. pd, py, pte--paddle, pygmy, platinum eye (I, I, I) "
4. mc, j--microcephalic, jet (V,V) "
5. Dch--Dachs (II) "
6. rb--ruby (V) "
7. mas--missing abdominal sternites (II) "
8. s--sooty (IV) "
9. sq-like (squint-like VIII?) "
10. mxp--maxillopedia (II) "
11. Mo--Microphthalmic (VI) "

12. fas3a--fused antennal segments (V)	"
13. p-- pearl (II)	"
14. B, ap--black, antennapedia (III, VIII)	"
15. b, apt--black, alate prothorax (III, II)	"
16. h, s--hazel, sooty (IV, IV)	"
17. b--black (III)	"
18. b^{t} --tawny (III)	"
19. Chr--Charcoal (III)	"
20. b^{d} --dusky (III)	New mutant, Manhattan, 1983
21. Rmal--Resistance to malathion (VI)	"
22. Rd-- Reindeer (II)	
23. Be, s --Bar eye, sooty (IV, IV)	
24. Fta--Fused tarsi and antennae (VII)	
25. Sa--Short antennae (VII)	
26. Spa, s--Spatulate, sooty (IV,IV)	
27. mas, au, s, rb, Rmal+, ap (multimarker strain).	

R.W. Beeman

SAN BERNARDINO, CALIFORNIA
CALIFORNIA STATE UNIVERSITY
BIOLOGY DEPARTMENT

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

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

Autosomal

63. p--pearl II New York 1976
64. p^{Pk}--pink II Chazy, 1959
65. p pearl II Park 1955
66. p^S pearl II
76. au--aureate III
78. b--black III
81. b^{S-1} -- 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
98. b^t--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
136. j^{AS}--jet V

Stock Lists

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_S VII, II	Corvallis 1975
180.	ap_D --antennapedia VIII	Berkeley 1962
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

Stock Lists

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
p^R---pearl riboflavinless II
r-red I
r,sh---red, short elytra
r^U---red
r^Z---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
thu^{S} --an allele of thu. IV
thu, Xl--thumbed, Extra large
umb--umbilicus

VI. Tribolium destructor

VII. Tribolium freemani

VIII. Tribolium madens

A. Sokoloff

A. Sokoloff

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

Red^{Ho} Via California State

White Via California State

ca Via California State

Paddle Via California State

Short antenna Via Purdue University

Tribolium confusum Via Carolina Biological Supply

Eliot Krause

SAVANNAH, GEORGIA
STORED-PRODUCT INSECTS RESEARCH AND DEVELOPMENT LABORATORY

I. Wild type strains

A. Lepidoptera

1. Anagasta kuehniella (Zeller)	N.C. State, Raleigh, N.C.
2. Cadra cautella (Walker)	Tifton, Ga.
3. C. figulilella (Gregson)	Unknown
4. Ephestia elutella (Hubner)	Richmond, Va.
5. Plodia interpunctella (hubner)	Modesto, Ca.
6. Sitotroga cerealella (Olivier)	Manhattan, Ka
7. Tineola bisselliella (Hummel)	Savannah, Ga.; Ottawa, Can., and Durham, N.H.

b. Coleoptera

1. Anthrenus flavipes LeConte	Savannah, and Durham
2. Attagenus megatoma (Fab.)	CSMA strains
3. Callosobruchus maculatus (Fab.)	Fresno, ca.
4. Cathartus quadricollis (Guerin--Meneville)	Unknown
5. Cryptolestes pusillus (Schonherr)	Tifton, Ga.
6. Dermestes maculatus De Geer	Madison, Wis.
7. Gibbium psylloides (Czenpinski)	Unknown
8. Lasioderma serricorne (Fab.)	Unknown
9. Oryzaephilus mercator (Fauvel)	Unknown
10. Oryzaephilus surinamensis (L.)	Manhattan, Kan.
11. Rhyzopertha dominica Fab.)	Unknown
12. Sitophilus granarius (L.)	Manhattan, Kan.
13. S. oryzae (L.)	Ark., Calif., Kan., La. Minn. and Tex.
14. S. zeamais Motchulsky	Estill, S.C.
15. Stegobium paniceum (L.)	Madison, Wis.
16. Tenebrio molitor (L.)	Manhattan, Ka, Durham, N.H.
17. Tenebroides mauritanicus (L.)	Savannah, Ga.
18. Tribolium castaneum (Herbst)	Unknown
19. Tribolium confusum duVal	Manhattan, Kan.
20. Tribolium madens Charpentier	Tifton, Ga.
21. Trogoderma glabrum (Herbst)	Madison, wis., Riverside, Ca.
22. T. inclusum LeConte	Madison; Riverside
23. T. variabile Ballion	Fresno, Riverside, Ca.

II. mutant strains

A. Plodia interpunctella

1. Scaleless (scl)	Savannah, Ga.
2. Melanic (m)	"

B. Tribolium castaneum.

1. Black mutant	Ocilla, Ga.
2. Black mutant	Savannah, Ga.

C. Tribolium confusum

1. Fused antennal segments	Savannah, Ga.
2. Short elytra	"
3. Crumpled elytra	"
4. Blade elytra	"
5. Umbilicus	"
6. Red eye pupae	

New mutants

1. peg-leg (pl)---autosomal recessive with appendages extremely reduced in length. Savannah

2. separated elytra (sep)---elytra divergent from proximal end. Savannah

3. creased elytra (cr)---elytra creased and distal portion divergent. Savannah.

R. Davis

STORRS, CONNECTICUT 06268
COLLEGE OF LIBERAL ARTS AND SCIENCES
THE BIOLOGICAL SCIENCES GROUP

1. Tribolium brevicornis (two vials)

2. Tribolium castaneum

   a. Chicago
   b. Veracruz
   c. Berkeley synthetic, marked with s.
   d. Chicago black, b.
   e. mc, p (microcephalic, pearl
   f. pygmy
   g. Davis Low Body Weight
   h. Davis High Body Weight

3. Tribolium confusum

   a. Chicago
   b. Yugoslavia
   c. Inbred (Group L CFI-B, culture 8d; Generation 123)
   d. b,p (black, pearl
   e. dj, e (disjoined, ebony)
   f. sh (short elytra

(Ed.).

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., Savannah, Ga.
A. elongatulus (Casey)	Madison, Wis.
Dermestes maculatus DeGeer	Madison, Wis., U. Minn.
Trogoderma variabile Ballion	Minnesota
Cucujidae	
Cathartus quadricollis (Guerin-Meneville	Savannah
Oryzaephilus surinamensis (L)	"
Silvanidae	
Ahasverus advena Waltl.	Minnesota
Tenebrionidae	
Cyaneus angustus (LeConte)	Winnipeg; Minnesota
Tribolium castaneum (Herbst)	Corvallis, Ore
Tribolium confusum duVal	Unknown
Bruchidae	
Acanthoscelides obtectus (Say)	Winnipeg
Anobiidae	
Lasioderma serricorne (Fab.)	Savannah, Ga.
Bostrichidae	
Rhizopertha dominica (F.)	Manhattan, Ka.
Curculionidae	
Sitophilus granarius (L.)	Unknown
S. oryzae (L.)	"
S. zeamais motsch.	Madison, Wis.

B. Lepidoptera

Pyralidae	
Anagasta kuehniella (Zeller)	Savannah, Ga.
Plodia interpunctella (Hubner)	Manhattan, Ka.
Gelechiidae	
Sitotroga cerealella (Oliver)	Savannah, Ga.

II. Mutant strains

Tribolium castaneum, wd (weird egg)	Corvallis, ore.

Attagenus elongatulus b (black) Madison, Wis.

(Ed.).

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

Coleoptera

Anobiidae
- Stegobiium 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.
T. 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

BELGIUM

GEMBLOUX
INSTITUT AGRONOMIQUE DE L'ETAT
ZOOLOGIE GENRALE

No updated list has been received (Ed.).

LOUVAIN
F.A.JANSSENS MEMORIAL LABORATORY FOR GENETICS
AGRICULTURAL INSTITUTE OF THE UNIVERSITY

No updated list has been received (Ed.).

BRAZIL

CAMPINAS, SAO PAULO
INSTITUTO AGRONOMICO, SECAO DE ENTOMOLOGIA

No updated list has been received (Ed.).

PIRACICABA, STATE OF SAO PAULO
CENTRO DE ENERGIA NUCLEAR NA AGRICULTURA
DEPARTMENT OF RADIOENTOMOLOGY

No updated list has been received (Ed.).

Stock Lists

CANADA

Winnipeg, Manitoba R3T 2M9
Research Station, CDA
195 Dafoe Rd.

All cultures are laboratory cultures maintained over several years. Geographic origins are not complete

Species	Origin
Cryptolestes ferrugineus	
C. turcicus	
Oryzaephilus mercator	
O. surinamensis	
Prostephanus truncatus	Mexico City, Mexico 1977
Rhyzopertha dominica	
Sitophilus granarius	
S. oryzae	
S. oryzae	Minnesota, USA 1982
Stegobium paniceum	
Tribolium audax	
T. castaneum	
T. confusum	

R.N. Sinha

COLOMBIA

BOGOTA, COLOMBIA
UNIVERSIDAD NACIONAL DE COLOMBIA
DEPARTAMENTO DE BIOLOGIA
APDO. AEREO #23227

Tribolium castaneum

Wild type strains

1. Apulo	Cundinamarca, Col. 1982
2. Bogota	Inst. Publ. Health, 1978
3. Bucaramanga	Trichogramma lab., 1981
4. Cartagena	Cartagena, Col. 1980

Mutant strains discovered in Colombia

antennapedia (1981)
bifurcated antenna (1980)
fused antennal segments (1980)
miniature appendaged (ma) (1981)
Charcoal (1979)
vestigial elytra (1981)
black? 1982
narrow eye (sq?) (1980)

dark grey eye (c?) (1980)
pearl eye (p?) (1982)
platinum eye (pte?) (1981)
Pk
rose eye (p ?) (1980)
deformed legs (dfl?) (1980)
twisted legs (1981)

Fernando Nunez del Castillo

(For original Spanish names of these mutants, see TIB 24, Ed.).

DENMARK

LYNGBY
STATENS SKADEDYRLABORATORIUM
(DANISH PEST INFESTATION LABORATORY)

Alphitobius diaperinus
Anobius punctatus
Anthrenus museorum
A. vorax
Attagenus alfieri
A. piceus
Dermestes frischi
Hylotrupes bajulus
Lasioderma serricorne
Oryzaephilus mercator
O. surinamensis
Rhizopertha dominica
Sitophilus granarius
S. oryzae
Stegobium (Sitodrepa) paniceum
Tenebrio molitor
Tenebroides mauritanicus
Thylodrias contractus
Tribolium confusum
T. destructor
Trogoderma granarium

(Ed.).

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

GERMANY

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.

INSTITUT FUR FLUGMEDIZIN DER DFVLR
GODESBERGER ALLEE 70
5300 BONN 2

I. Wild type strains derived from crop imports from Africa and Far East, selected against rough anomalies

A. Tribolium castaneum, not inbred.
B-1. T. confusum, not inbred
B-2. T. confusum, inbred by 12 single-pair passages

II. C. T. castaneum, a highly inbred strain (C-1) from Prof.

Bell, Purdue University, which showed more than 505 different anomalies during first generations in our laboratory.

C-1. T. castaneum, wild type strain.
C-2. T. castaneum, mixed mutations strain.

W. Briegleb

ISRAEL

TEL AVIV, ISRAEL
TEL AVIV UNIVERSITY
DEPARTMENT OF ZOOLOGY

A. Tribolium castaneum

1. Wild type strains

Berkeley--via Tribolium Stock Center, San Bernardino
McGill--via Tribolium Stock Center (TSC).
3 strains collected from different stored products, in Israel.

2. Mutant strains

Visible mutants
Chicago b via Stony Brook, N.Y.
eu++ (extra urogomphi, normal body color)
eu b (extra urogomphi, black body color)
p--pearl. From TSC
mc--microcephalic. Originated as a single mutant in p.
pd--paddle--From TSC.
pd b--paddle, black
py,r--pygmy, red from TSC.

electrophoretic mutants

bEs (slow esterase, b)--selected from b.
bPs (Acph-1 slow, est-1 null, b) selected from eu b.
PF (fast Acid phosphatase, + body color). Selected from eu+.

B. Tribolium confusum

Wild type strains
Chicago +--from TSC.
Israel

Mutant strains
- McGill b--via Stony Brook
- msg melanotic stink glands (prothoracic)--from TSC.
- msg (strong)--from TSC
- p (pearl) from TSC.
- XL (extra large) from TSC

c. T. brevicornis

Riverside + via TSC.

David Wool

JAPAN

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

Psocoptera	
Liposcelis bostrychophilus Badonel	Wild
Coleoptera	
Silvanidae	
Oryzaephilus surinamentsis (L.)	Wild
Cucujidae	
Cryptolestes sp.	Wild
Tenebrionidae	
Gnathocerus cornutus (Fabricius)	Wild
Latheticus oryzae Waterhouse	Wild
Palorus ratzeburgi (Wissmann)	Wild
Tribolium castaneum (Herbst)	Wild
T. confusum Jacquelin du Val	Wild
T. freemani Hinton	Wild
Anobiidae	
Lasioderma serricorne (Fabricius)	Wild
Stegobium paniceum (L.)	Wild
Bostrichidae	
Rhyzopertha dominica (Fabricius)	Wild
Curculionidae	
Sitophilus oryzae (l.)	Wild
S. zeamais Motschulsky	Wild
Bruchidae	
Callosobruchus chinensis (L.)	Wild

Stock Lists

Lepidoptera
- Phycitidae
  - Ephestia elutella (Hubner) — Wild
  - E. cautella (Walker) — Wild, brown mut. strain
  - E. kuhniella (Zeller — Wild
    - Mutant:
      - b black wing mutant
      - p1-1 white larval color strain
      - p1-2 " " " "
      - p1-9 red larval color strain
      - p1-10 " " " "
      - p1-11 Intermediate larval color strain
      - p1-12 " " " "
      - p1-13 " " " "
  - Plodia interpunctella (Hubner) — Wild
- Gelechiidae
  - Sitotroga cerealella (Olivier) — Wild

O. Imura

Note: Dr. H. Nakakita"s list in TIB 24 also includes the following information on Tribolium stocks:

Wild type strains and geographic origin

Tribolium audax H......derived from Dr. D.G.H. Halstead, Slough
T. castaneum (H.) Japan
T. castaneum (H.)
TCP.A (PH3-resistant)--derived from Dr. R.G.Winks, Stored Grain Research Lab, Division of Entomology, CSIRO
CTC4 (PH3-susceptible)--derived from R.G. Winks
T. confusum...........Japan
T. freemani........... captured in Japan (contaminated imported corn from Brazil).

H. Nakakita

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.	Rhysopertha 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.	Choetospila elegans	Okayama
3.	Lariophagus distinguendus	Okayama

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

Bruchidae

Callosobruchus chinensis

10 wild type strains from different localities in Japan. Black colored mutant derived from one of the geographical strains.

C. maculatus

10 wild type strains from different localities in the world.

C. analis

C. phaseoli

Zabrotes subfaciatus

Acanthoscelides obtectus

K. Fujii

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	Edinburch, 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
58. wine r^w 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
66. pink p^{Pk} 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

SLOUGH, BUCKS
MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
THE INSECTARY OF THE PEST INFESTATION CONTROL LABORATORY

The object of this insectary is to provide constant supplies of storage insects and for this purpose the species listed are bred in controlled conditions. On request insects are sent, without charge to educational bodies if commercial firms are unable to supply them. The insects are maintained in constant temperature rooms at a relative humidity of 70%, except in the case of cockroaches where the relative humidity is 50%. As far as possible insects are bred free from disease. All new stocks pass through quarantine precautions before acceptance into the insectary.

Incorporated into the list is the name of the country from which the stock bred in the laboratory originated. However, it is only recently that records of this information have been kept, and since many species have been maintained in culture for over 20 years they are of unknown origin. Some species, such as Attagenus fasciatus were sent to us from entomologists working abroad; but other species such as Ephestia cautella, were obtained from infested produce brought to this country, so that there is only circumstantial evidence that produce and pests originated in the same country. In the latter case the name of the country is bracketed.

Limited stocks of the following species are cultured and may be available in small quantities at certain time of the year: Thylodrias contractus Mots., Dinarmus basilis (Rondani) (=laticeps (Ashmead)), Chaetospila elegans (Westw.), Amphibolus venator Klug., and Pyralis farinalis (L.).

Stock Lists

Anthribidae				
Araecerus fasciculatus (Deg.)	Coffee bean weevil (Cacao weevil)		25	25
Bostrichidae				
Prostephanus truncatus (Horn)	Larger grain borer		25	25
Rhyzopertha dominica (F.)	Lesser grain borer		1	30
Bruchidae				
Acanthoscelides obtectus (Say)	Dried bean beetle (American seed beetle)	W.Africa	27	30
Acanthoscelides obtectus (Say)	" " "	Portugal	27	30
Acanthoscelides obtectus (Say)	" " "	N.Germany	27	25
Callosobruchus analis (F.)	Chinese beetle		29	25
Callosobruchus chinensis (L.)	Cowpea weevil		30	25
Callosobruchus maculatus (F.)	Southern cowpea weevil	Sierra Leone	29	30
Callosobruchus maculatus (F.)		Burma	29	30
Callosobruchus phaseoli (Gyll.)		Malaya	28	25
Callosobruchus rhodesianus (Pic)		Swaziland	28	25
Caryedon serratus (Oliv.)	Groundnut seed beetle (Groundnut bruchid) (Groundnut borer)		19	30
Zabrotes subfasciatus (Boh.)	Mexican bean beetle		16	25
Cerylonidae				
Murmidius ovalis (Beck)		Ceylon	7b	25
Cleridae				
Necrobia rufipes (Deg.)	Copra beetle (Red-legged ham beetle)		24	30
Necrobia ruficollis (F.)		Bangladesh	24	30
Cucujidae				
Cryptolestes capensis (Waltl)			6	25
Cryptolestes ferrugineus (Steph.)	Rust red grain beetle		8	25/30
Cryptolestes pusilloides (Steel & Howe)		(Canada)	6	20
Cryptolestes pusillus (Schön.)	Flat grain beetle		6	25
Cryptolestes turcicus (Grouv.)			8	20
Cryptolestes ugandae Steel & Howe		(East Africa)	6	20
Curculionidae				
Sitophilus granarius (L.)	Grain weevil	(Russia)	1	25
Sitophilus oryzae (L.)	Rice weevil	Britain	1	25
Sitophilus zeamais Motsch.	Maize weevil		1	25
Dermestidae				
Anthrenocerus australis (Hope)	Australian carpet beetle	(Britain)	22	25/20
Anthrenus flavipes LeC.	Furniture carpet beetle		22	30
Anthrenus olgae Kalik		Poland	22	20
Anthrenus sarnicus Mroczkowski			21	20
Anthrenus verbasci (L.)	Varied carpet beetle	Britain	21	20
Attagenus brunneus Faldermann		(Spain)	21	30
Attagenus nr. fasciatus (Thunberg)		Botswana	12	25
Attagenus unicolor (Brahm) (=megatoma (F.))	Black carpet beetle		22	30
Attagenus pellio (L.)	Fur beetle	Britain	21	20
Attagenus rufiventris Pic		Botswana	11	25
Attagenus smirnovi Zhantiev		Kenya	11	20

Stock Lists

Dermestes ater Deg.	Black larder beetle	Britain	23b	25
Dermestes frischii Kug.	Hide beetle	(Nigeria)	23b	25
Dermestes haemorrhoidalis Küster		Britain	23b	25
Dermestes lardarius L.	Bacon beetle	Britain	23a	25
Dermestes maculatus Deg.	Leather beetle		23b	25
Dermestes peruvianus Castelnau		Britain	23a	25
Trogoderma angustum (Solier)		(Germany)	2	25
Trogoderma anthrenoides (Sharp)		U.S.A.	2	25/30
Trogoderma glabrum (Herbst)		U.S.A.	2	25
Trogoderma granarium Everts	Khapra beetle	(Britain)	2	30
Trogoderma grassmanii Beal		U.S.A.	11	25
Trogoderma inclusum LeC.	Larger cabinet beetle		6	25
Trogoderma irroratum Reitt.		Egypt	2	30
Trogoderma ornatum (Say)		U.S.A.	11	25
Trogoderma simplex Jayne		U.S.A.	2	25
Trogoderma sternale plagifer Casey		New Mexico	20	25
Trogoderma variable Ballion		U.S.A.	2	30
Languriidae				
Pharaxonotha kirschi (Reitt)	Mexican grain beetle	Portugal	11a	20
Mycetophagidae				
Typhaea stercorea (L.)	Hairy fungus beetle	Nigeria	3b	25
Nitidulidae				
Carpophilus dimidiatus (F.)	Corn-sap beetle	(Amer.)	17	25
Carpophilus hemipterus (L.)	Dried fruit beetle		16	25
Trogositidae				
Lophocateres pusillus (Klug)	Siamese grain beetle		6	30
Tenebroides mauritanicus (L.)	The Cadelle	Pakistan	9	30
Tenebroides mauritanicus (L.)	"	Britain	9	30
Ptinidae				
Gibbium psylloides (Czenp)	Hump beetle	Britain	11a	20
Mezium affine Boield.		Britain	11a	20
Mezium americanum (Lap.)	American spider beetle		11a	20
Niptus hololeucus (Fald.)	Golden spider beetle	Britain	11a	20
Pseudeurostus hilleri (Reitt.)		Britain	11a	20
Ptinus clavipes Pans.	Brown spider beetle	Britain	11a	20
Ptinus exulans Er.		Britain	11a	20
Ptinus pusillus Sturm			11a	20
Ptinus sexpunctatus Pans.			11a	20
Ptinus tectus Boield.	Australian spider beetle		20a	25
Stethomezium squamosum Hint.	African spider beetle	Britain	11a	20
Tipnus unicolor (P. & M.)		Kenya	11a	20
Trigonogenius globulus Sol.	Globular spider beetle	Ireland	11a	20
Trigonogenius particularis Pic		Kenya	13a	20
Silvanidae				
Ahasverus advena (Waltl)	Foreign grain beetle	(W.Africa)	8	25
Cathartus quadricollis (Guer.)	Square necked grain beetle	W. Africa	8	25
Oryzaephilus mercator (Fauv.)	Merchant grain beetle		8	25
Oryzaephilus surinamensis (L.)	Saw-toothed grain beetle		8	25

Stock Lists

ORDER	COMMON NAME	COUNTRY OF ORIGIN	CULTURE MEDIUM	REARING TEMPERATURE °C
COLEOPTERA contd.				
Tenebrionidae				
Alphitobius diaperinus (Panz.)	Lesser mealworm		11	25
Alphitobius laevigatus (F.)	Black fungus beetle		5	25
Alphitophagus bifasciatus (Say)	Two banded fungus beetle	Britain	2b	25
Gnatocerus cornutus (F.)	Broad horned flour beetle		11	25
Gnatocerus maxillosus (F.)	Slender horned flour beetle		5	25
Latheticus oryzae Waterh.	Long headed flour beetle		5	30
*Palembus dermestoides (Fairm.)		Malaya	12	25
Palembus ocularis Casey		Jamaica	14	25
Coelopalorus foveicollis (Blair)		Trinidad	13	25
Palorus laesicollis (Fairm.)		Kenya	13	25
Palorus ratzeburgii (Wissm.)	Small eyed flour beetle		5	25
Palorus subdepressus (Woll.)	Depressed flour beetle	Turkey	5b	25
Sitophagus hololeptoides (Cast.)		Trinidad	12	25
Tenebrio molitor L.	Yellow mealworm		8a	25
Tenebrio obscurus F.	Dark mealworm		6a	25
Tribolium anaphe Hint.		Nigeria	11	25
Tribolium audax Halstead	American black flour beetle	Canada	11	25
Tribolium brevicornis LeC.		USA	26	25
Tribolium castaneum (Herbst)	Rust red flour beetle	Britain	26	25
Tribolium confusum J.du V.	Confused flour beetle		26	25
Tribolium destructor Uytt.	Dark flour beetle	(Holland)	11	25
Tribolium madens (Charp.)	Black flour beetle	(Yugoslavia)	11	25

*(= Martianus dermestoides Fairm.)

ORDER	COMMON NAME	COUNTRY OF ORIGIN	CULTURE MEDIUM	REARING TEMPERATURE °C
LEPIDOPTERA				
Pyralidae - Phycitinae				
Ephestia (Cadra) cautella (Walk.)	Tropical warehouse moth (Almond moth, dried currant moth)	(S. Africa)	6a	25
Ephestia (Cadra) cautella (Walk.)	" " " "	Cyprus	15	25
Ephestia (Ephestia) elutella (Hübn.)	Warehouse moth (Tobacco moth, Cacao moth)	Britain	6a	25
Ephestia (Cadra) figulilella Gregs.	Raisin moth	Cyprus	6a	25
Ephestia (Anagasta) kuehniella Zell.	Mediterranean flour moth (Mill moth)	Britain	6a	25
Plodia interpunctella (Hübn.)	Indian meal moth	Britain	6a	25
Pyralidae - Galleriinae				
Achroia grisella (F.)	Lesser wax moth		10	25
Corcyra cephalonica (Stainton)	Rice moth	(Burma)	6a	25
Galleria mellonella (L.)	Honeycomb moth		10	25
Galleria mellonella (L.)	" "	U.S.A.	4	25
Gelechiidae				
Sitotroga cerealella (Oliv.)	Angoumois grain moth		1	25
Tineidae				
Tinea columbariella Wocke			22	20
Tineola bisselliella (Humm.)	Common clothes moth		22	20
Tinea flavescentella Haw.		(Scotland)	22	20
Tinea metonella Pierce & Metcalfe		(East Africa)	22	20

Stock Lists

MUTANT STOCKS

	MUTATION	COUNTRY OF ORIGIN	CULTURE MEDIUM	REARING TEMPERATURE °C
Lasioderma serricorne (F.)	Black	U.S.A.	5	25
Rhyzopertha dominica (F.)	Black		1	30
Callosobruchus maculatus (F.)	Giant		26	30
Cryptolestes pusillus (Schön.)	V.dark	Trinidad	8	25
Dermestes maculatus Deg.	Black/Brown	Australia	23	25
Carpophilus dimidiatus (F.)	Pearl-eyed		8	25
Ahasverus advena (Waltl)	V. dark	Britain	8	25
Oryzaephilus surinamensis (L.)	Small	Burma	8	25
Tribolium castaneum (Herbst)	Giant		26	25
	V.dark	Britain		
	Bar-eyed?	Britain		
Tribolium confusum J.du V.	Black		26	25
	Pearl-eyed	Britain		
	Black & pearl-eyed			

Silvanidae (mutants)

Oryzaephilus mercator	pearl eye	Slough 1978
Oryzaephilus surinamensis	pearl eye	Slough 1978

Tenebrionidae (mutants)

Tribolium castaneum

sooty (s)	Berkeley 1977
black (b)	Berkeley 1977
tawny (b^t)	Berkeley 1977
jet (j)	Berkeley 1977

Tribolium confusum

red (r^y)	Berkeley 1977
eye spot (es)	Berkeley 1977
pearl eye (p)	Slough 1958
dirty pearl eye (dpe)	Berkeley 1977
ebony-2 (e_2)	Berkeley 1977
riboflavinless, pearl (p^r)	Vancouver 1977
black (b)	Berkeley 1977
melanotic stink glands (msg)	Berkeley 1977
ruby spot (rus)	Berkeley 1977
thumbed (thu)	Berkeley 1977
ebony (e)	New York 1977
blistered elytra (ble)	Berkeley 1977
disjoined (dj)	Berkeley 1977
umbilicus (umb)	Savannah 1977
claret	Berkeley 1978
ruby (rub)	Berkeley 1978

Also available occasionally:-

Amphibolus venator Klug
Chaetospila elegans (Westw.)
Dinarmus basilis Rondani (= laticeps (Ashmead))
Thylodrias contractus Mots.

Some strains which are periodically renewed from the field

Species and date of last addition:-

Sitophilus granarius (L.)	1970
Sitophilus oryzae (L.)	1970
Sitophilus zeamais Motsch.	1970
Oryzaephilus surinamensis (L.)	1976
Tribolium castaneum J.du V.	1975
Ephestia kuehniella Zell.	1975

CULTURE MEDIA

The letter "a" after a number (on previous pages) indicates that drinking water is added to the culture either in the form of damp blotting paper or as a corked tube of water containing a wick of blotting paper.

No.	FOOD	Weight Ratio (Ounces)
1.	Wheat	
2.	Wheat + wheatfeed	7:3
3.	"Farex" + Yeast + Honey + Glycerol	2:1:1:1
4.	Wheat + wheatfeed + glycerol on a damp pad of cotton wool	7:3:1
5.	Wheat + wheatfeed on a damp pad	7:3
6.	Wheatfeed + yeast	10:1
7.	Wheatfeed + yeast on a damp pad	
8.	Wheatfeed + yeast + glycerol	10:1
9.	Beetle culture (Family Bostrichidae)	
10.	Wheatfeed + rolled oats + yeast	5:5:1
11.	Wheatfeed + rolled oats + yeast + groundnuts	5:5:1:1
12.	Wheatfeed + rolled oats + yeast + groundnuts + cork	5:5:1:1
13.	Wheatfeed + rolled oats on a damp pad	2:1
14.	Rolled oats + yeast	10:1
15.	Rolled oats + yeast + sultanas	6:1:6
16.	Wheatfeed + rolled oats + yeast + glycerine + honey + broodcomb	5:5:1:2:2:2
17.	Wheatfeed + fishmeal + yeast	8:4:1
18.	Wheatfeed + rolled oats + fishmeal + yeast	5:5:2:1
19.	Fishmeal + yeast	16:1
20.	Fishmeal + yeast + flannel	16:1
21.	Fishmeal + yeast + bacon ends	16:1
22.	Fishmeal + yeast + bacon ends + cheese	16:1
23.	Wholemeal flour + yeast	12:1
24.	Wheatfeed + rolled oats + flour + yeast	3:3:3:1
25.	Wheatfeed + grassmeal + yeast + shortex	20:10:1:2
26.	Groundnuts	
27.	Haricot beans	
28.	Butter bean	
29.	Cowpeas + dried green peas	1:1
30.	Maize	
31.	Wheatfeed + glucose + yeast + glycerol	8:2:1:2
32.	Wheatfeed + fishmeal + yeast + cholesterol	8:8:1:1

(Ed.)

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 outsed 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

Stock Lists

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

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

NEW MUTANTS

Report of R. W. Beeman

New Homeotic Mutants

1. *Stubby* (*Stb*). This mutation was induced by ethyl methane sulfonate (EMS). It was found as a single female sired by an EMS-treated father. *Stb* is very similar to *Dachs* (*Dch*) and maps to a similar location on linkage group 2. *Stb* differs from *Dch* in the following ways: both produce a "short antennae" phenotype, but unlike *Dch*, *Stb* is completely penetrant and has a strong, uniform expression. *Dch* usually causes shortening and fusions of the tarsal and tibial segments as well, whereas *Stb* only rarely produces this phenotype, and then only weakly. As a result, *Stb* males are more successful sexual competitors than *Dch* males. *Stb* is homozygous lethal, whereas *Dch* is homozygous viable. Both *Stb* and *Dch* fail to complement *mxp*, but the failure of complementation is complete with *Stb* and only partial with *Dch*. *Dch* suppresses *mas-p* recombination but has no effect on recombination between *mas*, and *mxp*. *Stb* has no effect on *mas-p* recombination, but eliminates all recombination over the region *Stb-mxp-mas*. Finally, *Stb* is often associated with sex-ratio distortion in favor of females. Some crosses involving *Stb* give a unit sex ratio in the progeny, but others produce more than 95% females.
2. *Notched genae* (*mxp*^{NG}). Gamma-ray-induced, dominant and homozygous lethal. The dominant phenotype consists of indentations or "notches" in the genae, just in front of the eyes. Fails to complement *mxp*. Adults that are genotypically *mxp*^{NG}/*mxp* have (in

addition to notched genae) a very strong mxp phenotype (stronger than homozygous mxp) including tarsi, tibiae and femurs on the maxillary and labial legs.

3. Gular sutures incomplete (Gsi). Gamma-ray-induced, dominant and homozygous lethal. Six independently-derived alleles have recently been found. Penetrance is incomplete. The dominant phenotype consists of incomplete fusion of the gular sutures in the labial region of the head. Occasionally Gsi/+ pupae and adults have dents in the pronotum, elytra-like buds projecting from the pronotum, or a miniature pronotum on the occipital region of the head. The Gsi alleles all fail to complement apt and have complete penetrance opposite apt. Gsi^{20}/apt adults have a prothoracic phenotype similar to homozygous apt. Gsi^{6}/apt pupae and adults have well-developed prothoracic elytra and usually die shortly after adult eclosion. Gsi/mxp adults have a labiopedia phenotype, but have normal maxillary palps.

4. Socketless (Skl). Gamma-ray-induced, autosomal dominant, but homozygous viability or lethality uncertain as of this writing. Penetrance is complete. The phenotype consists of incomplete development of the first and second abdominal sternites (which normally form the sockets of the metathoracic coxae) and a homeotic transformation of the eighth abdominal segment into the seventh. The effect on A1-2 is similar to missing abdominal sternites (mas), but Skl beetles have normal A3 sternites. The ventral surface of A8 is normally membranous, but in Skl adults an A8 sternite develops that strongly resembles A7.

5. Notch (N). Gamma-ray-induced, dominant, homozygous lethal. The dominant phenotype consists of paired notches in the posterior margin of the sixth abdominal sternite, resembling those normally seen only in the posterior-lateral margins of the seventh sternite. I interpret this as a homeotic A6→A7 transformation. Notch fails to complement the partially pointed abdominal sternites (ppas) mutant. Penetrance is complete opposite ppas.

6. pointed abdominal sternite (pas^{30}). Gamma-ray-induced, recessive, homozygous viable and fertile. Allelic to ppas. Penetrance is complete. Expression is very strong and uniform, and only A4 is affected. This contrasts with ppas, in which expression is relatively weak and variable, and A5 is sometimes affected. The order of dominance is wild-type>pas^{30}>ppas.

Other New Mutants

7. Blunt abdominal and metathoracic projections (Bamp). Gamma-ray-induced, autosomal dominant. Similar in appearance to the previously described mutant of the same name (now extinct) (M. A. Hoy et al., TIB9:60 [1966]), except that the major effect is a blunting of the medial anterior metathoracic projection. The effect on the medial anterior projection of the third abdominal sternite is less pronounced. Homozygous viability has not been determined as of this writing.

8. Divergent elytryl tips (Det). Gamma-ray-induced, autosomal dominant. The proximal 2/3 of the elytra are normal, but the distal 1/3 appear symmetrically shrunken, divergent along their inner margins, and buckled to produce a small, round dome (not a blister) near the lateral margin of each elytron. Expression is very uniform. Homozygous viability not determined as of this writing.

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* Egg fertility and egg size of Tribolium confusum Duval. (Coleoptera: Tenebrionidae) on new foods.

The eggs of the confused flour beetle are clearwhite, oval and sticky. The characteristics of an egg can be readily determined when it is washed free of adhered flour particles. The pulse, Lathyrus sativus is grown in different parts of the world and is used as a food in various forms. It is found to contain a neurotoxin, β-N - oxalyl-amino-l-alanine, which is responsible for a serious disease of the spinal cord, called lathyrism in Man, if more than 50% of the diet contains this pulse.

Fertility factors are usually studied to evaluate their frequency in nature, to elucidate the evolutionary forces that maintain the between set limits and to describe at various levels (morphological, cytological, physiological and biochemical) any anomalies found (Trippa et al., 1980). Egg size is of prime importance to taxonomists. Fertility constitutes one of the important factors for the survival of an insect population.

The present study deals with the effect of L. sativus flour on the fertility and egg size of T. confusum which seem important from the point of nutritional regulation of the beetle.

Approximately 500 beetles were collected from a culture on wholemeal flour maintained at the Department of Zoology, Rajshahi University. The beetles were put on a thin film of wholemeal flour in a Petri dish (9 cms in diameter) for oviposition. Eggs were sieved on the next day and were incubated. Neonate larvae, 300 for each food, were transferred to glass jars (25.40x11.43 cms) with the help of a sable hair brush containing food media, viz.wholemeal flour (control), L. sativus flour and a mixture of both in equal proportions. The mouths of the jars were covered with a fine netted cloth. Insects were checked at intervals for pupation. Fresh pupae were sexed by the method of Halstead (1963). They were segregated according to sexes in separate Petri dishes. Newly emerged adults, in pairs of different sexes, were placed in separate vials (3.5x1.8 cms) containing foods. For each food 15 pairs of T. confusum were employed for oviposition. Eggs were counted after sieving the contents of the vials at 3-day intervals for 45 days. Eggs were put in Petri dishes and were observed for hatching. Fertility is defined in the present investigation as the percentage of first-instar larvae that emerge from an accurately known number of eggs as in the work of Park et al. (1961). For determining the egg size of T. confusum, eggs were collected on the day following the onsets of oviposition and were washed in 0.9% normal saline solution to rid them of adhered flour particles. They were now measured for length and width by a micrometer at 40X. The experiments were carried out in an incubator set approximately at 30°C.

The fertility data are shown in Table 1 and the egg sizes are given in Table 2. It was observed that L. sativus flour reduced the fertility of T. confusum significantly ($P < 0.001$). Any factor affecting the physiological state of the female may possibly induce a change in fertility. Unfortunately very little attention has been paid to a proper understanding of the effects of diets on insect fertility. Because fertility has a direct bearing on offspring production, the reduced fertility observed in the present work seems very much promising for the control of the pest nutritionally.

L. sativus flour significantly reduced the length (variance ratio = 12.81) and the width (variance ratio = 16.67) of T. confusum eggs ($P < 0.001$). Thus from the results it appears that the effect of the flour is to vary egg dimensions. This implies that the nature of the rearing medium must be taken into consideration for any biometric analysis with the eggs.

The authors wish to extend sincere thanks to Dr. M. A. Hossain, Chairman, Department of Zoology, Rajshahi University for providing necessary laboratory facilities.

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Table 1. Fertility of *Tribolium confusum* females grown on new foods.

Foods	Fertility(%) Mean ± S.D.	95% conf. limits lower	95% conf. limits upper	Co-efficient of variance, C.V.(%)	d-values	No. of eggs.
a. Wholemeal flour.	64.77± 6.40	61.53	68.30	9.88	-	4869
b. *L. sativus* flour.	49.46± 5.09	46.88	52.04	10.29	12.55	2053
c. Mixture of wholemeal and *L. sativus* flours	60.57±7.15	56.95	64.19	11.80	4.0	4073

Table 2. Eggs size of *Tribolium confusum* on new foods (mms).

Foods	Length Mean ± S.D.	Length 95% conf. limits lower	Length 95% conf. limits upper	No.	Width Mean ±S.D.	Width 95% conf. limits lower	Width 95% conf. limits upper
a. Wholemeal flour	0.660 ± 0.044	0.645	0.674	35	0.417±0.042	0.403	0.430
b. *L. sativus* flour	0.604± 0.049	0.587	0.620	35	0.370±0.024	0.362	0.377
c. Mixture of *L. sativus* and wholemeal flours.	0.625±0.043	0.610	0.639	35	0.391±0.027	0.382	0.399

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Genetic and environmental influences on pupal weight loss in Tribolium

Body size of Tribolium is an excellent polygenic trait for model experiments in population genetics (See Bell, 1982 for a comprehensive review). The genetic and phenotypic inter-relationships among various characteristics influencing body size are complex. In describing the growth patterns of 19 genetically diverse Tribolium populations, Englert and Bell (1969) reported that selection for three primary traits (13-day larval weight, pupation time and pupal weight) had produced profound effects upon the total growth and developmental complex. In addition to the three primary traits, three secondary traits (number of larval molts, adult emergence time and adult weight) reflected significant genetic correlations with the primary traits.

The genetic inter-relationships of these various manifestations of growth may influence the results from single-trait selection experiments. For example, "pupal weight" has been widely used as a model polygenic trait, but the experimental outcome may be significantly influenced by something as simple as changes in experimental or observational procedures. In our laboratory we have usually observed "pupal weight" as body weight taken within the first 24 hours after pupation. Thereby the observation is independent of developmental rate (pupation time) and pupal metabolic weight loss. In contrast, Enfield (1977) and others have observed pupal weight at a fixed number of days after egg-lay. Such traits as 19 - or 21-day pupal weight have been used successfully in model experiments and have considerable experimental advantage over "first day pupal weight", but one should recognize as they extrapolate from such findings that they are compound traits involving among other things intense stablizing selection for a uniform rate of development. That is, all individuals still in the larval stage at 19 or 21 days (late pupators) will be discarded and not even observed while the early pupators will be handicapped or advantaged (depending on the direction of selection) due to pupal metabolic weight loss. In fact, this latter trait (body weight loss during the pupal stage) in itself is an interesting trait and should be examined further as an experimental model for studying metabolic efficiency when food resources are limited and fixed. Bell and Burris (1973) noted that losses in pupal weight differed significantly for different methods of selection and were not simply proportional to body size. In a recent study of long-term bi-directional selection responses (Bell, et al. 1985), we made a similar finding for both weight loss and days required for adult metamorphosis.

In an effort to learn more about the nature of pupal weight loss, individual pupae from a pedigreed unselected base population were observed to determine the influence of pupation time, sex, initial weight, days in storage and storage temperature on pupal weight loss.

MATERIAL AND METHODS

The genetic material for this study resulted from single pair random matings taken from the unselected Purdue "+" Base Population of Tribolium castaneum maintained in our laboratory. A 24-hour egg collection from each of 39 single pair matings was taken in half-pint bottles with standard medium (whole wheat flour with 5% yeast) and cultured at 33°C and 70% R.H. Individual pupae were screened from each mating on a daily basis with a record taken for date of pupation, sex, and initial weight in deca-micrograms on a Mettler Micro-balance. The offspring from each fertile mating were divided at random into two groups of five (when available) with Group 1 stored at 25°C and Group 2 stored at 18°C. On Day 21 after the eggs were collected, all pupae from one-half of the matings were weighed and discarded. Then on Day 24, all pupae from the remaining matings were weighed and discarded. Thereby for each offspring we had a record as to (1) mating (2) sex (3) days to pupation, (4) initial pupal weight (5) storage temperature, 18°C or 25°C, (6) final weight on Day 21 or 24, (7) days in storage, and (8) weight loss measured as initial weight minus final weight.

The trait of primary interest here, pupal weight loss, was analyzed by the following statistical model:

$$Y_{ijklm} = \mu + W_i + b(ND) + M(W)_j + T_k + b(NDT) + TM(W)_{ij} + WT_{ik} + S_l + WS_{il} + SM(W)_{jl} + TS_{kl} + WTS_{ikl} + TSM(W)_{ijk} + \Sigma_{ijklm}$$

Y_{ijklm} = the dependent variable loss

μ = overall mean

W_i = fixed effect of the ith Weigh Day, i = 21 or 24

$b(ND)$ = covariate effect of the number of days in storage

$M(W)_j$ = random effect of the jth mating nested within weigh days 21 or 24, 1, ..., 11.

T_k = fixed effect of the kth Trt, k = 1,2.

$b(NDT)$ = covariate effect of N Days by Trt interaction

$TM(W)_{jk}$ = effect of the interaction Trt by Mating

WT_{ik} = effect of the interaction Weigh Day by Trt

S_l = fixed effect of sex, l = 1,2.

WS_{il} = effect of the interaction Weigh Day by Sex

$SM(W)_{jl}$ = effect of the interaction Sex by Mating

TS_{kl} = effect of the interaction Trt by Sex

WTS_{ikl} = effect of the interaction Weigh Day by Trt by Sex

$TSM(W)_{jkl}$ = effect of the interaction Trt by Sex by Mating

$\Sigma_{(ijkl)m}$ = random variation not included in other terms in the model.

RESULTS

The analysis of variance for weight loss during the pupal stage based on the above statistical model is given in Table 1.

Table 1. The analysis of variance for pupal weight loss

Source	df	SS	F
Weigh Day	1	498.005	107.71***
N Days	1	123.685	25.51***
Mating (W)	20	96.977	2.22**
Trt	1	400.306	186.05***
ND x Trt	1	54.962	25.55***
W Day x Trt	1	.910	.42
Trt x Mating (W)	20	43.031	.99
Sex	1	2.539	.53
W Day x Sex	1	1.645	.43
Sex x Mating (W)	20	96.718	2.21**
Trt x Sex	1	.311	.09
Trt x Sex x Mating (W)	20	66.030	1.51*
$\Sigma_{(ijkl)m}$	130	283.859	

The most striking aspect of these results is the multitude of significant influences, genetic and environmental, on pupal weight loss even after the trait has been adjusted for number of days in storage. In spite of a pupa's superficial appearance of quiescence, the pupal stage is a period of high metabolic activity. Significant genetic influences (mostly additive gene effects) are identified by variation due to "mating" and the "Sex x Mating" interaction. The significant environmental influences of Weigh Day, N Days (days in storage) and Temperatures Treatments are illustrated in Figure 1.

In view of the limited scope of this preliminary study, the results depicted here are consistent. As expected, weight loss increase linearly with time in storage and the loss was significantly larger in the warmer storage where metabolism presumably would be faster than at the cooler temperature ($b_{\mathrm{LOSS.\ N\ Days}} = +1.02 \pm 0.18$ dμg for 25°C and $+0.61 \pm 0.21$ dμg for 18°C). The significant "ND x Trt" interaction is obvious from Figure 1 and suggests an increasing metabolic rate toward the end of the storage period in 25°C while the weight loss appears to be slowing down in the cooler 18°C.

The phenotypic inter-relationships between the various traits observed here will not be discussed in detail but are listed in Table 2.

Table 2. The phenotypic relationships between various traits expressed as coefficients of correlation with levels of probability (.01).

	Pupation Time	N Days	Initial Weight
Weight Loss	- .332 (.0001)	+ - 601(.0001)	+ .005 (.9351)
Pupation Time		- . 631(.0001)	+ .208 (.0019)

An effort to examine weight loss as a function of initial weight was unfruitful with the limited amount information available in this study. This may have resulted from the insignificant phenotypic correlation between these two variables (Table 2). Intuitively, we had expected the pupal weight loss to be correlated positively with initial pupal weight. Apparently, that was not the case under the conditions of this experiment. Obviously, this point deserves further investigation.

SUMMARY

Pupal weight loss as influenced by sex, initial weight, pupation time, storage temperature, and days in storage was studied in the Purdue "+" unselected Base Population of *Tribolium castaneum*. Significant genetic variation was observed for weight loss independent of the other variables to suggest an underlying genetic influence on metabolic efficiency in the utilization of the fixed food resource available for adult metamorphosis.

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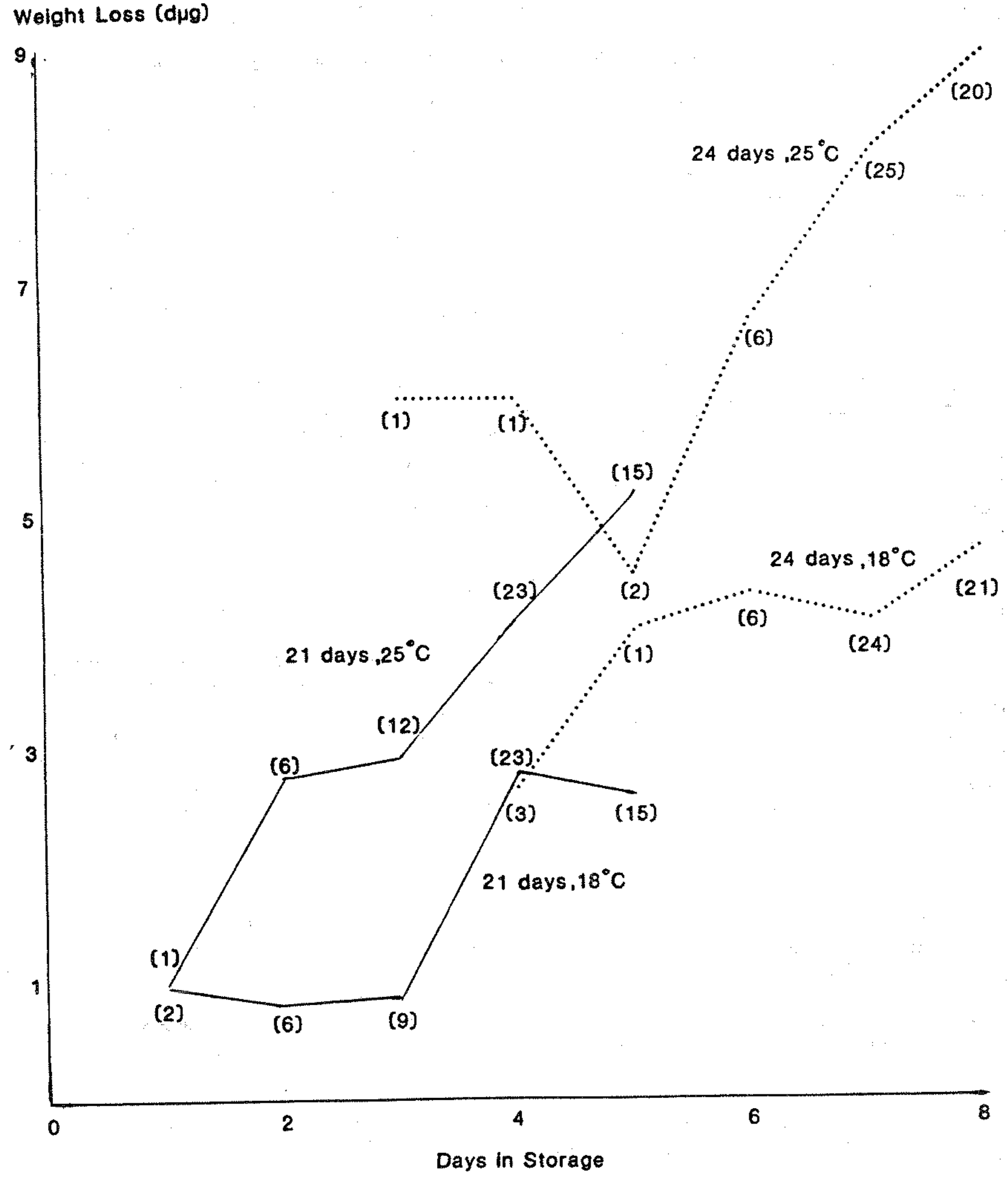

Figure 1. Graphic presentation of pupal weight loss as influenced by storage temperature and days in storage. (Number of observations at each point are given).

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* Effect of pulse flours on the formation and duration of various stages of *Tribolium confusum* Duval. (Coleoptera: Tenebrionidae)

The confused flour beetle, *Tribolium confusum* Duval. is a notorious pest of a great variety of stored commodities althrough the globe. Pulses and their products are used as foods in different parts of the world. As stored products they are also liable to the attack of a large number of pests. The rate of infestation of an insect is directly linked with the production of offspring and the duration of various developmental stages. The present investigation aims at determining the effect of various pulse flours, viz. gram (*Cicer arietinum*), pea (*Pisum sativum*) and red lentil (*Lens esculenta*) on different stages of *T. confusum*.

Adults of *T. confusum* were extracted from a laboratory culture maintained on wholemeal flour in the Department of Zoology, Rajshahi University, Bangladesh and were put on a thin film of wholemeal flour for the collection of eggs. Eggs collected on the following day were incubated in a Petri dish for hatching. Two sets of experiments were performed. In the first set of experiments, 220 neonate larvae were put on foods, viz. wholemeal (control), gram, pea and red lentil flours in separate glass jars (25.40 x 11.43 cms) secured at the top with muslin to note the percentage of different stages formed. Insects were checked from time to time for pupation. Freshly formed pupae were put on Petri dishes for adult emergence. The percentages of pupae and adults formed on various flours were thus recorded. In the second set of experiments, 120 newly hatched larvae were reared on the above foods in similar ways. Larval and pupal periods were carefully noted on different foods. All the experiments were conducted at 29 ± 1°C.

All the pulse flours reduced the production of pupae ($P<0.02$) and pea and red lentil flours reduced the emergence of adults ($P<0.001$) (Table 1). Pulse flours lengthened larval periods of *T. confusum* ($P<0.001$). However, gram and pea flours shortened the pupal periods of the beetle ($P<0.001$) (Table 2). Hasan (1984), working on the effect of green and red gram flours on the same insect, observed reduced productions of pupae and adults. He also observed lengthened larval periods of the insect on these foods. Ali (unpublished data) observed that the pulse, *Lathyrus sativus* reduced the production of pupae and adults of the beetle. Besides he recorded a lengthened larval period of the insect on this flour. It is obvious from the results that a significantly lower number of adults would reduce the rate of infestation considerably and this would be strengthened by a lower number of generations a year. This seems promising in days when there is a growing concern over the control of insects nutritionally.

The authors are gratefull to Professor M. A. Quayum and Dr. Md. Sayedur Rahman for extending necessary laboratory facilities.

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Table 1 Effect of pulse flours on the formation of various stages of *Tribolium confusum*

Foods	Stages			
	Pupae		Adults	
	No.	Percentages	No.	Percentages
a. Wholemeal flour	198	90.00	191	86.81
b. Gram flour	177	80.45	174	79.09
c. Pea flour	76	34.54	72	32.72
d. Red lentil flour	153	69.54	153	69.54

Table 2 Effect of pulse flours on the larval and pupal periods of *Tribolium confusum* (days)

Foods	Developmental stages			
	No.	**Larval periods**	**No.**	**Pupal periods**
a. Wholemeal flour	82	17.45 ± 4.12* (16.86 - 18.64)	67	5.37 ± 0.50 (5.26 - 5.48)
b. Gram flour	61	28.93 ± 3.87 (27.96 - 29.90)	35	4.80 ± 1.41 (4.33 - 5.27)
c. Pea flour	48	24.39 ± 3.78 (23.32 - 25.46)	45	4.51 ± 1.01 (4.22 - 4.80)
d. Red lentil flour	57	26.78 ± 2.54 (26.12 - 27.44)	44	5.61 ± 1.61 (5.14 - 6.08)

* Mean ± SD
Figures in parentheses indicate 95% confidence limits

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Notes-Research

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*The position of black, aureate and light ocular diaphragm in *Tribolium confusum*—Preliminary Results

Three autosomal mutants, black(b), a semidominant mutation affecting body color; the recessive aureate(au), causing a three-fold increase in the number of body hairs and the recessive light ocular diaphragm(lod) have been found to be linked in *T. castaneum*. Sokoloff (1977) determined that the genes recombined differently in the two sexes: In the males *b-au*, *b-lod* and *au-lod* recombined at a frequency of 37.4 ± 1.3%, 21.0 ± 1.5% and 18.3 ± 1.2%, respectively, while in females the recombinant values were 39.8 ± 1.8%, 14.0 ± 1.3% and 27.7 ± 1.6% respectively. The order of the genes in the two sexes was *b-lod-au*.

Similar mutants have been discovered in *T. confusum*. Therefore, it is of interest to determine whether these genes are homologous, and to what extent the map position of these mutants is similar. The purpose of this note is to give some preliminary data to establish the relative position of these genes in *T. confusum*.

A stock of black, aureate and light ocular diagphragm beetles(also homozygous for pearl to facilitate the identification of *lod*) was obtained from the Tribolium Stock Center, California State University, San Bernardino, and mated with normal Sacramento +/+. The F1 then were crossed back to *b-au-lod*. A total of 822 beetles were counted.

The results are shown in Table 1.

The frequency of recombination for *b*, *au* and *lod* in the two sexes were as follows:

	Females	Males
b-au	37.0 ± 1.59%	33.8 ± 1.75%
b-lod	47.2 ± 1.61%	46.2 ± 1.70%
au-lod	32.4 ± 1.66%	32.8 ± 1.41%

Although the *b-au* recombination values in the two species are similar, the *b-lod* and *au-lod* values are different. Furthermore, it appears that the order of these genes is different in the two species. In *T. castaneum* the most distant genes are *b-au*, while in *T. confusum* *b-lod* are farthest apart. However, because of the identical recombination values for the females in the *b-au* and *au-lod* segments and the close values for the same segments in the males, further crosses are necessary to establish the correct order of the genes. Such experi-ments are now in progress.

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Table 1. Backcross progeny from T. confusum (A) baulod female X baulod/+++ male and (B) the reciprocal cross from 12 successful matings(numbers in parenthesis are decimal fractions of the total).

Phenotype	Cross A	 B
+++	40 (.185)	147 (.243)
baulod	50 (.231)	112 (.185)
++lod	23 (.107)	51 (.084)
bau+	23 (.107)	91 (.150)
+aulod	17 (.079)	41 (.068)
b++	39 (.181)	97 (.160)
+au+	18 (.083)	53 (.087)
b+lod	6 (.027)	14 (.023)
Total	216	606

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Competitive ability of Tribolium castaneum (Coleoptera Tenebrionidae) selected for high and for low sensitivity to the environment in periodically refreshed medium.

Abstract

The competitive ability of T. castaneum lines selected for high and for low responsiveness to environment was observed in competition with a mutant strain of T. confusum

In the first stage of competition all T. castaneum lines had a higher biomass than T. confusum. At this stage, among the T. castaneum selected lines (HR vs. LR), the high responsiveness lines were better competitors.

The outcome of the competition was the exclusion of T. castaneum from all the encounters. Among the selected lines, the low responsiveness of egg production showed a longer time until extinction than the high responsiveness lines.

Introduction

The flour beetles *Tribolium castaneum* and *Tribolium confusum* are both cosmopolitan species infesting granaries and flour plants, but they do not coexist either in nature in laboratory experiments. In the present study, competition experiments will the above species, were out in order to observe whether selection for responsiveness to the environment as measured by the influence of conditioned (used) flour on the egg production, affected the competitive viability of the selected lines.

Positive changes in one characteristic, producing increases in fitness, are often assumed to bring about negative changes in other life-history characteristics, resulting in decreases in fitness. The gestion as to how these conflicts among life-history characteristics are resolved has become a central issue in population biology (viewed by Stearns, 1980).

The HR (high responsiveness) and LS (low responsiveness) lines of T. castaneum were in a selection program for high and low responsiveness to the environment as measured by egg production (Lavie, Ritte and Moav, 1978). The environment in these in these experiments is the medium, flour, which varies from fresh (not used previously by beetles) through various degrees of conditioning. The degrees of conditioning. The degree of conditioning depends on the period of time and number of beetles using the flour.

The selected lines could not be observed in competition with one another, since free matings would have annihilated immediately the difference between the lines. Therefore, the lines were compared by their performance in competition with a blude mutant strain of *Tribolium confusum* (CF). This procedure makes possible a comparison both between the selected *I. vastaneum* (CS) lines and between the two competing species.

Both species of *Tribolium* display cannibalistic behavior of adults and larvae on eggs and pupae. Therefore, during interspecific competition, this additional cause of death makes the intrinsic growth rate (r) play an important role in the competitive ability. Competitive ability is a combined function of K, (carrying capacity of the environment), r, and α (coefficient of competition). As a result it is difficult to predict which of the two, the low of the high sensitivity lines is expected to possess the higher competitive ability.

In terms of growth rate, the high sensitivity lines are superior. Lavie, Rirre and Moav (1981) found that the high responsiveness line developed faster than the low responsiveness line. When fecundity is basically high, as in *Tribolium*, the most efficient means for increasing growth rate is the shortening of developmental time (Lewontin, 1965).

In terms of carrying capacity, the low responsiveness lines are likely to be superior. The carrying capacity of the selected lines was not measured but, on theoretical grounds, the low responsiveness lines are expected to have higher K than the high responsiveness lines based both on the frequently observed negative correlation between K and r and the character involved. The low response lines where beetles continue to lay eggs in spite of the deterioration of the environment, will attain higher K values than the high response lines, where oviposition almost ceases in deteriorated environments.

The criterion used to assess competitive ability was time until extinction (in terms of total dry weight) during the first stage of competition - before the first case of extinction occurred.

Methods

i) The genetic stocks

Tribolium castaneum lines (CS):

Selection for egg production responsiveness (Lavie et al., 1978) carried out in the two wild populations (Rehovot and Be'er Sheva) and a synthetic population, assembled from beetles collected all over Israel, yielded the following lines:

3) Rehovot high responsiveness of egg production (HR)
4) Rehovot low responsiveness of egg production (LR)
5) Be'er Sheva high responsiveness of egg production (HR)
6) Be'er low responsiveness of egg production (LR)
7) Synthetic population high responsiveness of egg production (HR)
8) Synthetic population low responsiveness of egg production (LR)

The Tribolium confusum (CF) used was an unselected strain marked with the mutant for black body color.

ii) Exprimental desigh and procedure

The experiment includes for each line, six replications of one species culture and six replications of CS : CF 1:1 mixed cultures. Each culture cual was initially populated with 12 ten-day old male-female pairs, in a baby food jar containing 40 g of standard medium (95% whole wheat flour and 5% dry brewer's yeast). The mixed cultures contained 6 ten-day old CS pairs and 6 ten-day old CF pairs. The vials were kept at a temperature of 29°C and 35% R.H.

Every four weeks the vials were sifted, the adults removed, and all juvenile stages returned to the same vial with 40 g fresh standard medium. The adults so remained were kept for 24 hours at 100 C and their dry weight recorded. The advantage of discarding the adults was stressed by Lerner and HO (1961) and this method was employed also by Dawson (1966). Dry weights of adults was measured also by Sokal and Kareen (1965). The experiment was concluded when for two consecutive census periods one of the species failed to recruit new adults.

iii) Analysis of competitive ability

1) Relative crowding coefficient.

The relative crowding coefficient (de Wit, 1960) represents a precise measure of the influence which one species has over the other. When, as in this case, the vitial proportion of the competitiors is 1:1, the relative crowding coefficient is simplified and the final formula becomes the relative proportion of the two competitors in mixed cultures versus their proportion in pure cultures.

$$C_{CS/CF} = \frac{MCS}{MCF} : \frac{PCS}{PCF},$$

MCS and MCF are the total dry weight in mixed cultures for the first four census periods (before any case of extinction was recorded), while PCS and PCF are dry weight in pure culture of T. castaneum and T. confusum, respectively. If CCS/CF>1, then CS is succeeding relative to CF. This criterion was used to evaluate competitive ability at the early stages of competition.

2) Time until extinction

The main criterion for competitive ability is time until extinction. It is considered to be the time elapsed between the start of the experiment and date of the last consus yielding at least one adult. It was calculated for each line as the mean time until extinction of the 6 mixed cultures replicates of that line.

3) Time until reversal of the ratio CS : CF.

Since in the early stages of competition, the species which eventually became extinct (CS), was more abundant than CF, the time until reversal of this relationship was recorded for each replicate and the mean was calculated for each line.

Results

Table 1 presents for each line the total dry weight during the first four census periods (before any extinction occurred) in pure cultured and in mixed cultures. These results were used to calculate the relative crowding coefficient presented in Table 2. In all the lines CCS/CF is greater than 1 implying that the early stage of competition T. castaneum. Comparing between the T. castaneum lines, all the high responsiveness lines show higher relative crowding coefficients than their opposite, low responsiveness lines.

Table 3 presents the data on the time until extinction is also the line with longer time until reversal of the ratio CS : CF. In all cases CS was the species that went ultimately extinct. The comparison between the T. castaneum reveals that all the LR lines survived longer than their opposed lines.

Discussion

The competition experiment with different selected lines of T. castaneum competing with mutant for black body strain of T. confusumenables both comparisons between the species and between the T. castaneum selected lines. In the early stage of the competition, before any extinction occurred, all T. castaneum lines were more successful than T. confusum, in terms of a high relative coefficient of crowding. This may be the consequence of both higher f for T. castaneum (Ziegler, 1976) and higher cannibalistic rate (Park, Mertz and Nathanson, 1968). Ryan, Park and Mertz (1970) found that adults and larvae of both species have the ability to discriminate between Cf and Cs prey preferentially eat more of the other species. Park et al. (1968) found that Cs is always more predatory and more selective.

Comparing the CS selected lines, the faster developmental time may be responsible for the fact that all high responsiveness lines have higher relative crowding coefficient values than the low responsiveness lines.

In spite of numerical superiority in the early stages of competition, the T. castaneum populations became extinct in every treatment. This may be the consequence of the higher carrying capacity for T.confusum. Cf suffers to lesser degree from the conditioning of the medium. When offered a choice of habitats, adults of T. confusum actively burrow into mildly conditioned flour (Ghent, 1963). Conditioned flour also prompts fewer adults of T.confusum to emigrate from an experimental habitat, than of T. castaneum in the same condition (Ogden, 1970). Productivity of CF is less influenced by crowding and conditioned media than for CS. CF also has a greater influence on CS does on CF, implying a higher coefficient of competition. Sokoloff and Lerner (1967) found than productivity of CF females in the presence of CS males was only slightly less than in the presence of males of their own species. The drop in productivity by CS females in the presence of CF males was much greater.

Comparing the CS selected lines, all lines of low responsiveness of egg production showed a longer time until extinction. This may be explained as in the comparison between species by their higher K.

For both the comparison between species and between the selected lines, it seems that for the early stages of competition the growth rate was the more influential, while the eventual outcome of the competition was directed mostly by the carrying capacity.

Similar results were obtained when the sensitivity to the environment was measured in terms of dispersal. The lines selected for high and for low dispersal (Ritte and Lavie, 1977) were observed for cannibalistic behavior and competitive ability by Zirkle et al. (submitted to Evolution). They found for the low dispersal line, a higher cannibalistic value and a higher competitive ability than for the low dispersal line.

Acknowledgements

This manuscript was prepared with the much appreciated help of Diave Adler. Discussions with Uzi Ritte were particulary stimulating.

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TABLE 1.

Cumulative dry weight means (in grams) and standard errors in inpure and mixed cultures for the first four census and relative crowding coefficient

Population, Line	Type of Culture			Relative crowding coefficient
	Pure	Mixed		CS/CF
		CS	CF	
CF	1,8954 + 0,124			
Rehovot				
HR	1,5917 + 0,194	1,3537 + 0,105	0,4431 + 0,07	3.637
LR	1,1158 + 0,092	0,9022 + 0,050	0,2048 + 0,02	2.593
Be'er Sheva				
HR	1,0825 + 0,060	0,6681 + 0,158	0,2842 + 0,03	1.343
LR	0,8646 + 0,102	0,7516 + 0,190	0,2895 + 0,03	1.184
Synthetic				
HR	1,3573 + 0,160	0,955 + 1,083	0,2698 + 0,01	4.943
LR	1,3240 + 0,200	1,2854 + 0,199	0,4174 + 0,15	4.409

TABLE 2.

Mean time and standard errors (in weeks) until extinction and reversal of the ratio CS : CF; and proportion of extinct replicas after 28 weeks

Population, Line	Mean time (weeks)		Proportion of extincted replicas after 28 weeks	Probabilities by Bailey for proportions	
	Until extinction	Until reversal of CS: CF ratio			
Rehovot					
HR	33.33 + 8.64	20.67 + 3.93	.33	t10=1.7191	p=0.1344
LR	38.67 + 11.50	25.33 + 6.57	0.00	t10=1.7191	p=0.1344
Be'er Sheva					
HR	22.00 + 4.90	17.33 + 2.07	1.00	t10=1.0957	p=0.3014
LR	27.33 + 3.35	21.33 + 4.68	.83		
Synthetic					
HR	27.33 + 10.25	23.33 + 2.53	.83	t10=5.4771	p=0.0001
LR	44.67 + 13.49	24.00 + 0.00	0.00		

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* A two locus genetic model for the responsiveness of egg production to conditioned medium in the flour beetle, Tribolium castaneum

Introduction

Several studies have shown that in addition to the control of the level of a quantitative trait, there may be an independent control of the responsiveness of this trait to the environment. Responsiveness is in fact a genotype x environment interaction. So far, the traits and organisms involved in these studies have been growth rate in Schizophyllum commune (Jinks and Connolly, 1973, 1975 ; Connolly and Jinks, 1975), growth rate in carp (Moav et al. 1975 ; Wohlfarth et al. 1983), final height and flowering time in Nicotiana rustica (Perkins and Jinks, 1968, 1971, 1973 ; Brumpton et al., 1977 ; Boughey and Jinks, 1978), and egg production in Tribolium castaneum (Lavie et al., 1978, 1984 ; Bolet et al., 1979).

The phenotypic value of a trait is determined by the genotype, the environment and the interaction genotype x environment. When the genotype x environment interaction represents a large proportion of the phenotypic variance, it implies that different genotypes will show the best performance in different environments, (Moav et al., 1975). This means that selection in a specific environment doesn't assure that the genotype selected as the best will show the best performance also in other environments. In cases where the selected genotypes are meant to perform in environments different from the environment in which they were selected, the responsiveness should be included in selection programs. In many cases, for example, selection for low responsiveness should be more important than selection for an optimal level of the trait.

Lavie, Ritte and Moav (1978) showed that responsiveness of egg laying to conditioned medium, in Tribolium castaneum, could be selected as a trait independent of egg production itself. In the three populations, statistically significant differences between the high responsiveness (HR) and the low responsiveness (LR) lines were obtained after one generation of selection, and these differences hardly changed in subsequent generations. It was concluded that (1) responsiveness for egg laying indeed has an independent genetic control, and (2) this control is caused by a small number of genes.

Lavie et al., (1984) presented the result for crosses between the HR and LR lines. In all three populations, the cross between HR females with LR males yielded responsiveness values as high or even higher than the HR line, indicating dominance for high responsiveness. The values of responsiveness encountered for the reciprocal crosses, ranging from lower than the LR line to higher than the HR line, suggest that more than one major gene is accounting for variation in responsiveness, and that maternal effect may also be involved. Therefore, a genetic model consistent with all the evidence gained in the selection program (Lavie et al., 1978) and the crosses between the lines (Lavie et al., 1984) is based on two complementary genes each possessing two alleles with dominance for high responsiveness. According to the suggested model, genotypes A-B-will show high response and genotypes A-bb, aaB,- and aabb low response. One locus exhibits maternal effects, expressed by higher response of A-B- when their mother was A- than when their mother was aa.

For the verification of the proposed genetic model three types of low response lines were needed AAbb (named line 1), aaBB (line 2) and aabb (line 3). In spite of the continuous distribution of responsiveness, Mendelian procedures were used in order to create the desired low response lines.

Materials and Methods

The genetic stocks used in this work, were Jaffa and Beer-Sheba populations, which were derived from wild populations of T. castaneum from two cities in Israel and named after them. These populations were used in the selection program (Lavie et al. 1978) and in the crosses between the selected lines (Lavie et al. 1984).

Experimental conditions and procedure as well as estimation of responsiveness (β') are as in Lavie et al. 1978.

The responsiveness of egg production was measured by comparing the net fecundity (number of eggs recovered) by virgin females in three types of flour: fresh, mildly-conditioned and highly-conditioned. The use of virgin females was in line with Yamada (1974), who showed that the genetic correlation between the egg laying of virgin and fecund females was 0.8 and Orozco and Bell (1974), who showed that in a selection program or egg production, a large amount of error variance is removed if selection is based on virgins.

The derivation of β' is as follows (Moav and Wolhfrath, 1974): in the conventional linear model, the performance of the jth genotype on the ith environment, g_{ij} , is partitioned into the average environmental effect (a_i), the average genetic effect (g_j), and a genotype x environment interaction (ga_{ij}): $g_{ij}=a_i+g_j+ga_{ij}$

Bucio Alanis (1966) partioned the interaction term into a linear function of the environmental deviation ($\beta_j a_i$) and a residual independent component (ς_{ij}), so that the equation gets the form: $g_{ij}=(1+\beta_j)a_i+g_j+\varsigma_{ij}$

Moav and Wohlfarth (1974) further divided β'_j into sg_j, which is the correlation of the inter-environment differences on g_j (not a true genetic interaction), and β'_j which is the specific responsiveness of genotype j to environment i. β'_j, which can serve as the unit of selection for responsiveness can be calculated from the equation: $g_{ij}=(1+\beta'_j)a_i+g_j+sg_j a_i+\varsigma_{ij}$

As the ranges of vary extremely from one experiment to another there are not fixed values named high or low responsiveness. In each experiment the responsiveness values of the different lines are compared, and the term high or low resposiveness is relative to the other results obtained in the same experiment.

Egg production was recorded as the mean number of eggs per day, counted after each 4-day period of egg laying, and corrected using the means of the corresponding Environmental control group (beetles kept always in fresh flour). This is the reason that occasionally the corrected values for net pecundity are negative.

Breeding Design

In each pair analyzed the β' was recorded for 4 of their daughters.

The breeding design will be detailed for every experiment separately. Each experiment by itself is not designed to prove the suggested model, because due to the extremely small samples (specified in the result tables) it suffers of a very low statistical power. Yet the evidence gathered from all the experiments becomes significant.

1. Establishment of the putative AAbb (line 1) and aaBB (line 2): As a start, beetles with the postulated genotypes AABb and AaBB were obtained from the crosses of LR mothers with HR fathers. The separation between AABb and AaBB was carried out according to the postulated maternal effect which should have caused AABb (originating from A-mothers) to have higher responsiveness values than AaBB (originating from aa mothers).

When in a LR x HR cross all 4 daughters had higher B values than the mid point between the parental lines, the postulatory genotype of the mating was AAbb x AABB and daughters from this cross were considered AABb. (The possibility of AaBb daughters if the mother was Aabb cannot be overuled.) Assuming free recombination between the two loci, the crosses designed to obtain line 1 and line 2 are detailed for line 1:

postulated genotype of parents:	AABb x AABb		
postulated genotype of offspring:	1/4 AAbb	1/2 AABb	1/4 AABB
expected responsiveness of offspring:	1/4 low response	3/4 high response	

Females from the lower quarter of β' values were considered AAbb and were mated to their brothers.

The genotype of the males was deduced from the responsiveness of their daughters. As the fathers used to obtain line 1 and line 2 are offspring of the above described cross the expected proportion of families with AAbb or aaBB fathers is 1/4. When all daughters showed lower β' values than the midpoint between the two selection lines, the male was considered AAbb (in line 1) or aaBB (in line 2).

2. Establishment of the postulated aabb line 3:

Due to the difficulty to recognize aaBB from aabb beetles both having always low values, the aaBB (line 2) group may also include aabb. Matings between the already obtained lines 1 and 2 served to eliminate beetles suspected of being aabb from line 2 and to establish line 3.

Three types of matings were performed:

postulated genotypes:	(1) AAbb x AAbb	(2) aaBB x AAbb	(3) AAbb x aaBB
expected responsiveness :	low response	higher-response than line 1	highest response

The within matings in line 2 were postponed to the stage of testing all low-responsiveness lines because it was preferable to use the available aaBB females in crosses with AAbb. When in a mating between the lines, all four investigated daughters showed low response, the postulated aaBB parent was considered aabb and was eliminated from line 2 and moved to establish line 3.

3. Tests of the obtained low-response lines.

The three low-response lines obtained by Mendelian procedures were tested together with LR and HR selected lines. (In Jaffa population the HR line was lost.) All three lines are expected to have low β' values.

4. The crucial test of the model

The crucial test of the model was performed in Jaffa population, the only population possessing three low-response lines.

This experiment included the same types of mating used to purify line 2 and establish line 3 but this time using the already purified line 2 in the mating with line 1, and an increased sample size.

The crucial cross is between postulated AAbb mother and postulated aaBB father. Both parents are low-responding, yet the offspring of this cross is expected to be high-responding. Due to the maternal effect, offspring of the reciprocal cross aaBB x AAbb are expected to show lower-response.

RESULTS:

1. Establishment of the putative AAbb (line 1) and aaBB (line 2). The results for the crosses designed to obtain line 1 and line 2 (see material and methods) are presented in Table 1 and Table 2.

The proportion of males postulated to be AAbb or aaBB fits extremely well the expectation of 1/4.

	Populations			
	Jaffa		Beer-Sheba	
Line	aaBB	AAbb	aaBB	AAbb
number of matings	8	8	4	13
number of selected males	4*	2	1	3

* In this line no family fulfilled the selection constriction and the four males were selected as in each case all their daughters showed responsiveness values lower than the HR line.

2. Establishment of the postulated aabb line 3.

The mean results for this experiment are presented in Table 3. All the low response lines tested, showed as expected, lower responsiveness values than the HR line.

In both populations the cross AAbb x aaBB had, as predicted, higher responsiveness values than the crosses within the AAbb. According to the maternal effect, crosses between the lines when AAbb serves as mother, are expected to have higher responsiveness values than the reciprocals. This expectation is met by both populations.

In Jaffa population line 3 (aabb) was established from 2 females from the aaBB line with all daughters showing lower responsiveness values than the midpoint between the LR and HR lines and a male from the aaBB line with three daughters showing lower responsiveness values than the midpoint and one daughter with a responsiveness value scarcely higher than the midpoint. In the Beer-Sheba population the aabb line was established from one male and one female with all daughters showing lower responsiveness values than the HR line.

Rearranging the results in Table 3 for the crosses AAbb x aaBB and aaBB x AAbb by eliminating families with one aabb parent, the following mean responsiveness values were obtained :

Jaffa				Beer-Sheba			
AAbb x aaBB	families of aabb fathers	aaBB x AAbb	families of aabb mothers	AAbb x aaBB	families of aabb fathers	aaBB x AAbb	families of aabb mothers
.182	.347	.091	-.250	-.397	-.632	-.611	-1.137

After this elimination of families with aabb parents from the between line 1 and 2 crosses, in both populations not only the offspring of AAbb x aaBB cross had a higher responsiveness value than line 1 but also offspring of aaBB x AAbb. Due to the maternal effect the AAbb x aaBB cross retained in both populations a responsiveness value higher than the reciprocal cross, as expected.

3. Tests of the obtained low response lines.

Mean results of all low response lines are presented in Table 4. In Jaffa population all low response lines, established through Mendelian procedures have lower responsiveness values than the LR line. Therefore, no comparison with the missing HR was needed.

In Beer-Sheba population all low response lines have responsiveness values lower than HR, as expected, but the aabb line has a value only scarcely lower than the HR line ; therefore, further crosses were performed only in Jaffa population.

4. The crucial test of the model.

The mean results for lines 1 and 2 and the crosses between them are given in Table 5. As predicted, the highest responsiveness value belongs to the cross AAbb x aaBB. It differs significantly from the low parent ($t_{30} = 3.25$, $p<0.01$) and also from the reciprocal cross (t_{64}, $p<0.01$) as predicted by the postulated maternal effect. Therefore, in spite of the difficulty to analyze quantitative continuous data by Mendelian techniques and in spite of the small samples and small statistical power of every single experiment, the evidence gathered from all the experiments involving the lines selected for high and for low responsiveness supports the proposed two locus genetic model:

1. The fact that the separation between the lines was achieved in all populations after one generation of selection, and was maintained without further progress in subsequent generations, suggests that responsiveness, although a quantitative trait, may be controlled by a small number of genes (Lavie et al., 1978).
2. In all populations, the cross between HR females with LR males yielded responsivness values as high or even higher than the HR line, yet, the values of responsiveness encountered for the reciprocal crosses, ranged from lower than the LR line to higher than the HR line, suggesting maternal effect and at least two major genes accounting for the variation in responsiveness (Lavie et al., 1984).
3. Variance of responsiveness in the LR lines was higher than in the HR lines in previous studies as well as in this study (with the exception of Beer-

Sheba responsinveness. This is in good accord with the model claiming that the LR lines include three non-responding genotypes (A-bb, aaB- and aabb) and mating between them may yield high responsiveness values.

4. In both Jaffa and Beer-Sheba populations the proportion of males compatible with the criterion for postulating then to be AAbb or aaBB in crosses designed to provide the AAbb and aaBB lines fits extremely well the expectation of 1/4.
5. The crucial test performed in Jaffa population was statistically significant, and the preliminary crosses performed in both Jaffa and Beer-Sheba population showed the same tendency i.e.: crosses between the two complementary low response lines yielded higher responsiveness values than the AAbb line, and the AAbb x aaBB cross had a higher responsiveness value than the reciprocal cross, as predicted by the maternal effect.

Discussion

An understanding of the genetic basis for responsiveness, can bring to new selection methods for economic traits. Many theoretical and experimental studies were dedicated to the intriguing problem of the best environment for selection (Mather and Jones, 1958; Jones and Mather, 1958 ; Falconer, 1960 ; Dickerson, 1962). Even in cases where there is a consensus that for maximal benefit selection should be carried out in an environment similar to the management level, in which the organism will perform, the fact that responsiveness is an independent trait with simple genetic control may provide new breeding possibilities.

Responsiveness can be regarded as a control system with only few genes (two in this case), shaping the polygenic system of the main genetic effect (egg production in this case). The continuous variation for responsiveness is due to the fact that the control genes are phenotypically expressed through their action on the structural polygenic system who exhibits continuous variation.

Polymorphism in the control system implies genotype x environment interactions, causing various genotypes to be the best in different environments. For these cases, especially when the environmental conditions are in a process of changing (either improvement by technological advances or deterioration following the need to reduce the cost of product), we suggest that the selection for the economical trait should be accompanied by selection for responsiveness.

High responsiveness should be favored when improvement in the management level is expected. (For high-responsive organising an improvement in environment will be accompanied by a considerable gain in the economic trait of interest). On the other hand, when reduction in cost of product is expected, a low responsiveness is preferable as the deterioration of environment will be accompanied by a relative small loss in the economic trait. The suggested method can be extremely useful when the final aim is to provide strains that will be able to cope with the future, but the exact future environment is not known or if this future environment won't be attained by one leap but in small steps. This condition holds true especially for developing countries, improving constantly the management level. It may also be useful to countries with economic problems that might force a reduction in the price of product and a deterioration of management level. When the change in environment is continuous, practicing selection for the economic trait, anew after each change in husbandry, will be both most costly and less efficient if their responsiveness was not taken into account when selected in the previous conditions.

Summary

1. A genetic model suggested for responsiveness consists of two complementary genes each possessing two alleles with dominance for high response. A high response beetle will be A-B. One of the loci exhibits maternal effect.
2. The three possible low response lines, AAbb, aaBB and aabb, were obtained through Mendelian procedures.
3. Crosses between the low response lines were performed and the obtained data were consistent with the expectations according to the genetic model.

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Table 1: Crosses intended to create AAbb and aaBB females

Net fecundity values (means and standard errors of the number of eggs laid per female per day) in fresh medium (NF1), mild medium (NF2), conditioned medium (NF3), and responsiveness (β') in the two populations

Population	Line Parameter	LR	HR	AAbb	selected females	aaBB	selected females
Jaffa	Number of beetles tested	9	13	41	10	38	9
	NF1	1.54 +.31	2.13 +.54	1.44 +.23	1.29	1.63 +.28	1.76
	NF2	1.47 +.57	.73 +.47	-.36 +.19	.75	1.07 +.28	1.36
	NF3	-1.64 +.53	-1.58 +.53	-1.12 +.20	.32	-1.74 +.27	.03
	β'	.83 +.202	.817+.132	.753+.073	.151	.866+.197	.288
eer-heba	Number of beetles tested	16	15	44	11	20	5
	NF1	4.22 +.68	1.26 +.28	2.29 +.29	3.26	1.89 +.38	2.98
	NF2	3.56 +.50	.05 +.15	1.94 +.24	2.02	1.64 +.36	2.55
	NF3	.59 +.53	-1.98 +.47	-.43 +.33	1.93	-1.05 +.14	.60
	β'	.795+ .144	.802+.144	.674+.076	.023	.780+.075	.442

Table 2: Crosses intended to obtain AAbb and aaBB males (for definitions of symbols see Tabl

Population	Line Parameter	LR	HR	AAbb	mean for progeny of selected males	aaBB	mean for progeny o selected males
Jaffa	Number of beetles tested	19	16	43	10	33	9
	NF1	4.23 +.49	4.95 +.60	4.99 +.36	4.08	5.52 +.50	5.22
	NF2	3.53 +.32	3.89 +.52	4.60 +.39	3.91	5.21 +.40	4.64
	NF3	3.13 +.33	2.06 +.17	3.15 +.24	3.70	3.40 +.32	3.05
	β'	.956+.146	.287+.123	.781+.094	-1.219	.840+.169	-.710
Beer-Sheba	Number of beetles tested	16	17	52	9	18	3
	NF1	6.12 +.42	4.28 +.50	6.42 +.28	5.28	6.03 +.53	4.38
	NF2	5.55 +.48	1.68 +.38	5.13 +.33	6.25	4.59 +.51	4.33
	NF3	5.19 +.41	2.91 +.21	5.44 +.29	6.03	3.96 +.29	4.67
	β'	.854+.188	.688+.202	-.277+.203	-2.020	.082+.35	-.942

Table 3 The experiments designed to eliminate aabb beetles from he AAbb and aaBB lines (for definitions of symbols see Table 1)

opu- ation	Line Parameter	LR	HR	AAbb	AAbb x aaBB	aaBB x AAbb
affa	Number of beetles tested	14	2	9	26	22
	NF1	4.41 +.72	5.5 +1.13	2.65 +.40	4.01 +.50	2.73 +.44
	NF2	4.41 +.56	1.88 + .13	2.55 +.46	3.52 +.31	2.15 +.28
	NF3	1.86 +.44	.50 + .25	1.14 +.43	1.22 +.19	1.01 +.20
	β'	.067+.171	.241+ .181	.060+.183	.113+.098	.060+.090
eer- heba	Number of beetles tested	19	17	11	11	11
	NF1	3.94 +.49	2.12 + .54	4.67 +.64	5.66 +.63	5.85 +.65
	NF2	3.84 +.52	1.01 + .27	4.32 +.49	5.00 +.57	5.71 +.67
	NF3	3.17 + .47	.91 + .15	3.14 +.38	2.80 +.33	3.30 +.35
	β'	.916+ .237	.010+ .170	-.791+.245	-.482+.144	-.964+.25

Table 4: Test for all Mendelian low-response lines (for definitions of symbols see Table 1).

Population	Line Parameter	LR	HR	AAbb	aaBB	aabb
Jaffa	Number of beetles tested	11		21	9	4
	NF1	1.86 +.31		2.51 +.23	4.34 +.81	2.06 +.57
	NF2	1.27 +.25		1.76 +.26	2.97 +.91	2.19 +.39
	NF3	1.02 +.29		1.22 +.23	1.72 +.39	1.13 +.63
	β'	-.127+.238		-.157+.175	-.165+.289	.415+.129
Beer-Sheba	Number of beetles tested	18	18	14	4	5
	NF1	4.13 +.47	1.84 +.39	4.03 +.59	2.59 +.43	2.48 +.27
	NF2	4.84 +.46	2.40 +.38	3.25 +.32	2.81 +.48	2.45 +.51
	NF3	3.65 +.50	.50 +.16	2.05 +.30	1.94 +.41	.90 +.33
	β'	-.524+.250	.688+.169	.274+.203	-.094+.437	.607+.337

Table 5: Crosses between the two Mendelian low-response lines - AAbb and aaBB in Jaffa populati

Line Parameter	AAbb	aaBB	AAbb x aaBB	aaBB x AAbb
umber of eetles tested	15	5	27	39
F1	2.89 +.53	3.55 +.58	4.19 +.26	3.94 +.32
F2	2.04 +.31	3.58 +.81	3.18 +.27	3.27 +.29
F3	1.81 +.53	3.70 +.36	2.15 +.09	2.80 +.20
β'	-.781+.271	-2.060+.703	-.589+.137	-1.215.129

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* Sexual dimorphism of mutants in Tribolium.

Previous reports have pointed out that certain sex-linked mutants are phenotypically differently expressed in the males and females of Tribolium. For example, in T. confusum, Striped, (a dominant with recessive lethal effects in the female and lethal in the male) exhibits a longitudinal white stripe in young St/+ females which eventually becomes pigmented in aged females. In males the elytra are completely white, and the males die, either at, of a few days after, eclosion. In T. castaneum the expression of pd is strongly sex- influenced: the fusion of the antennameres in females is restricted to the two distal segments of the club. In males, all three club segments fuse into a paddle and the funicular segments are variously fused, resulting in a considerably shorter antenna.
Unexpectedly, the phenotypic expression of an autosomal mutaant in T. castaneum and another in T. confusum, have proved to be sex-influenced in the first case, and sex-limited in the second.
THE BLE, blistered elytra, gene in T. castaneum may produce blisters on one or both elytra, but penetrance is incomplete (so that some ble/ble males and females may appear completely normal) and expression is variable ranging from beetles having a minute blister one elytron only, to beetles in which huge blisters may appear in both elytra. However, in those beetles in which blisters form, the blisters occur in different regions of the elytra. In ble/ble females the blisters for at the distal ends of the elytra. In males, on the other hand, the blisters occur laterally and about the middle of the elytra. Sometimes the blisters are small, and it is necessary to examine both elytra to make sure that blisters are not present.
the other mutation, tentatively given the name reduced juvenile urogomphi, "rju", was found in a strain of T. confusum maintained by brother-sister mating for 123 generations. The adult beetles from this stock which otherwise would have been discarded, were saved in an attempt to produce a homozygous stock. After several generations it has become clear that females fail to exhibit the trait, but in males the rju trait is strongly,but variably, expressed. Further experiments are on their way.

MUTANTS CLASSIFIED ACCORDING TO BODY PARTS AFFECTED

TABLES PREPARED BY A. SOKOLOFF AND M. HANI SOLIMAN

(Note: Alleles of mutants have not been included unless the allele produces an effect different from that produced by the mutant included in the list)

Table 1. Known wing mutants in Tribolium castaneum

Symbol	Name of mutant (phenotypic effects)
aa	abbreviated appendages (elytra and legs short)
akb	akimbo (deformed elytra)
bal	ballooned (blisters on the elytra)
bet	bent elytral tips
bj	banjo (elytra separated)
ble	blistered elytra
by	bumpy
cspl	concave split (elytra divergent)
cye	curly elytra
dre	droopy elytra (elytra divergent)
dve	divergent elytra
ele	elongated elytra
ohs	overhung split (elytra longer than abdomen and divergent).
pe	pointed elytra (more pointed than dve)
re	reduced elytra (elytra often missing)
ro	rough (elytra with rough appearance)
rue	rugose elytra (adults with roughened elytra)
sb	split back (elytra either short or split)
sh	short elytra (similar to sb)
spce	split curved elytra (similar to cspl and cye)
spl	split (elytra separate at distal ends)
te	truncated elytra (elytral tips bent under more proximal portion of elytra)
vge	vestigial elytra
we	warped elytra

Table 2. Homeotic mutants in T. castaneum.

Symbol	Name of mutant (phenotypic effect)
ap	antennapedia (antennae modified to legs)
apt	alate prothorax (elytra-like growth on prothorax)
lp	labiopedia (labial palps modified into legs)
mxp	maxillopedia (maxillary palps modified into legs. Labial palps may also be modified into leg-like structures)
ppas	partially pointed abdominal segments (second apparent segment acquires a medial sternal projection mimicking the appearance of the first apparent abdominal segment. Pupal muscles persist into the imago stage).
sta	spikes on trochanters and antennae (spikes appear on any segment of the antenna and/or on the trochanters)

Table 3. Mutants with modified antennae in T. castaneum

Symbol	Name of mutant and phenotypic effect
atf	antennae and tarsi fused
bal	ballooned (uplifted elytra resulting from blister on membranous wings)
bb	blob (in extreme form segments 3-11 fuse to form a large mass. In less extreme form any of the funicular and club segments may fuse)
bd	bead (antennal segments are elongated or reduced in size)
bra	branched antenna (antenna modified into two or more branches. May be a manifestation of sta)
d	denotched (gena is eliminated; scape and pedicel are fused, and the antennae are held vertically)
da	deformed antenna (club segments fused)
Dch	Dachs (fusion between segments 5-8 of the funicle and 9-10 of the club. In extreme form all the legs may become short. In some specimens there may be two sex-spots the effect resembling that of engrailed in Drosophila melanogaster).
Df	Deformed antenna (club segments fused)
elb	elbowed antenna (there is no reduction in segment number, but the pivotal segment where the elbow forms may be reduced in size)
fas-1	fused antennal segments-1 (involves fusion of segments 4-5 of the funicle and 9-10 of the club)
fas-2	fused antennal segments-2 (involves fusion of funicular segments 5-6)
fas-3	fused antennal segments-3 (involves fusion of funicular segments 5-6 and 6-7)
fas-3a	fused antennal segments-3a (involves fusion of segments 3-5, and 6-7 or 6-8 and club segments 9-10, 10-11 or funicular and club segments 8-11)
Fas-4	Fused antennal segments-4 (involves fusion of segments 3-4, 5-6. and 9-10)
Fas-5	Fused antennal segments-5 (involves fusion of segments 4-5, 5-6, 6-7, 3-8 or 6-8)
Fta	Fused tarsi and antennae (as a result of fusion, the antennae are reduced to about seven segments, and the tarsi of all legs reduced to a single podomere, and this single tarsus may become fused with the tibia)
pd	paddle (in females only segments 9-10 are fused, while in the male there is a fusion of segments 9-11 to form a paddle, and the funicular segments are fused to a great extent)
pec	pectinate antenna (fusion of funicular and/or club segments 3-4, 5-6, 6-7, 7-8, 8-9, 9-10 or more than two segments)

Table 3. (continued)

sa	short antenna (antennal segments fused producing a curved antenna; leg femurs may be short and thick)
Sa	Short antenna (recessive lethal. Sa/+ has shorter antennae than +/+ due to the reduction in number and fusion of the six funicular segments)
ser	serrate (fusion of the funicular segments and/or the club. Tarsi may also be fused)
Spa	Spatulate (fused funicle and/or club segments which fuse into the form of a spatula)

Table 4. Body color mutants in T. castaneum

Symbol	Name of mutant and phenotypic effect
b	black
b^{cd}	cordovan (an allele ob b)
b^{d}	dusky (an allele of b)
b^{t}	tawny (an allele of b)
Chr	Charcoal (a pseudoallele of b)
j	jet (darker than s and lighter than b)
my	mahogany (deep reddish brown. Pigment takes five days to a week to become fully pigmented)
s	sooty (body color identical in appearance to +/b)
sp	spotted (easily recognized in teneral adults)
wa	white appendages (appendages break off easily)

Table 5. Mutants affecting eye shape in T. castaneum

Symbol	name of mutant and phenotypic effect
Be	Bar eye (number of ommatidia reduced to produce a bar eye)
cfl	confusum-like (interocular distance between compound eyes in the adult equal to two eye-diameters on the ventral side of the head)
gl	glass (corneal lenses fail to develop. Eye appears flat, smooth and shiny)
mc	microcephalic (compound eyes reduced or missing, uni- or bi-laterally; occiput reduced in size; blind beetles with no eyes may be selected from the stocks with ease)
mc^{eg}	microcephalic with eye growth from the gena (the growth may resemble the antenna)
Mo	Microphthalmic (In adult the ommatidia of the compound may appear disarranged or they may be reduced in number producing a smaller eye. The cranium behind the gena is more or less reduced in size. The head may be retracted into the prothorax up to the level of the eyes)
Ren	Reduced eye notch (as in mc, but eye is not affected. No reduction in size of occiput)
sq	squint (compound eye external to the ocular diaphragm fails to form. The ocular diaphragm is reduced, and the ocular foramen may be missing. The beetles are blind)
sq-l	squint-like (phenotypically identical to sq but not allelic to it)

Table 6. Eye color mutants in T. castaneum

Symbol	Name of mutant and phenotypic effect
c	chestnut
h	hazel (reddish-brown to dark-brown. Distinguishable from wild type at all ages)
i	ivory (similar to pearl)
lod	light ocular diaphragm (the black pigment from the ocular diaphragm is eliminated so the beetles eyes are no longer spectacled
m	maroon (color ranges from maroon to almost black)
M^r	Modifier of red (dark red to burgundy in $r\ M^r/$ males and $r\ M^r/r\ M^r$ females. $r\ M^r/r\ +$ females do not have red eyes, but they are black as in wild type. This gene acts both as a modifier and a suppressor. It is the best known case of intra-locus heterosis)
p	pearl (both larval stemmata and pupal and adult ommatidia are pigmentless. The eye may appear "spectacled" because the underlying ocular diaphragm, an endoskeletal structure, develops black pigment similar in appearance to that produced in the ommatidia)
p-l	p-like (allelic to ivory)
p^{Pk}	pink (dominant to, and allelic to pearl. Young beetles have pearl eyes which become pinkish with age)
pte	platinum eye (allelic to rg. Ommatidia lack pigment as does the p mutant to which rg beetles resemble)
r	red (ommatidia range from light pink to dark burgundy)
r^D	red of Dawson (sex influenced: light red in males. Very dark red in aged females)
r^{ph}	peach (an allele of r. Ommatidia appear reddish pink)
r-1	red-1 (ommatidia of wild type have blackberry red granules while r-1 have yellow and pink granules)
rb	ruby (eye slightly lighter in color than chestnut)
rg	ring eye (ommatidia lack back pigments. Centre of compound eye is crystalline as in pearl. Allelic to pte)
rs	rose (red eye in pupa and young adults)
w	white (no visible pigments)

Table 7. Leg mutants in T. castaneum.

Symbol	Name of mutant and phenotypic effect
bf	bowed femur
bl	bowed leg
bt	bent tibia-1
btt	bent tibia-2
dff	deformed femur (femur of forelegs bent forward or may be reduced)
dfl	deformed legs (tibia of any leg can become short and curved. Identifiable in the larval, pupal and adult stage)
dft	deformed tibia
dhl	deformed hind leg
dpm	deformed podomeres
ims	incomplete mesosternum (frees coxae of mesothoracic legs)
pg	pegleg (whole leg beyond the coxa is absent, or only the tarsus in adults and the pretarsus in the larva are missing)
ti	tarsal irregular (tarsal segment of mesothoracic reduced from five to four. The prothoracic and metathoracic legs may be affected)
wl	white leg (one or more legs may lose pigmentation and break off)

Table 8. Mutants affecting the appendages in Tribolium

Symbol	Name of mutant and phenotypic effect
	T. castaneum
dim	diminutive appendages (resembles ma in having all appendages shorter)
ma	miniature appendaged (stunted body, podomeres of all appendages and elytra are shorter and divergent)
stu	stumpy (fusions of segments in all appendages or reduction of podomeres and antennameres. Antennae consist of two segments, mouth parts have reduced segment number, legs consist of coxa and claws only)
wa	white appendages (legs and antennae pigmentless and breakable)
	T. confusum
ma	miniature appendaged (stunted body and shorter appendages (antennae, elytra and legs) similar to the ma gene in T. castaneum)
stt	stunted
stu	stumpy (similar in effect as stu in T. castaneum)

Table 9. Mutants with pleiotropic effects in T. castaneum

Symbol	Name of mutant and phenotypic effect
ap	antennapedia (affects antennae, metathorax and distal tarsal segments)
Be	Bar eye (affects eye and antennae. Recessive lethal effects)
Df	Deformed (affects eyes and antennae. Recessive lethal effects)
Fta	Fused tarsi and antennae (affects antennae, elytra and tarsi. Recessive lethal effects)
gdf	grossly deformed
Gi	Giant (increases body weight twofold over normal)
ma	miniature appendaged (affects the whole body)
Mo	Microphthalmic (affects eye and head. Recessive lethal)
pd	paddle (affects the antennae and tarsi)
pok	pokey (divergent elytra, fused antennal segments and shorter and thicker leg segments. Prolongs larval developmental time)
ptl	prothoraxless (different degrees of missing prothorax. Forelegs may be deformed with femur and tibia shorter and thicker, or may be vestigial. The four-legged beetles cannot mate or dig tunnels in the flour and they die prematurely)
ptl-1	prothoraxless-1 (allelic to ptl and ptl^D but with stronger expression and better viability)
py	pygmy (reduced body weight to half of the normal)
rta	reduced tarsi and antennae (Fused antennameres 4-5. Club segments are fused in males. Tarsomeres are reduced by 1-2 segments per leg or they may not form at all)
sa	short antenna (affects antennae and femora)
Sa	Short antenna (affects antennae and tibiae. Recessive lethal)
ser	serrate (affects antennae and tarsi)
slk	sleek (affects various organs of the head, antennae, wings, legs)
tro	troll (compact body; abbreviated appendages, tarsomeres reduced by one or two segments)

Table 10. Mutants in Tribolium with behavioral interest

Symbol	Name of mutant and phenotypic effect
	T. castaneum
cos	corn oil sensitive (It would be of interest to learn whether it has a behavioral preference for corn oil)
eju	elongated juvenile urogomphi
em	emasculated (sex limited. Normal testes and accessory glands, but aedeagus fails to evert)
eu	extra urogomphi (one or two additional urogomphi in the larva)
Eu	Extra urogomphi (extra set of urogomphi. Males with no intromittent organs may also be produced)
msg	melanotic stink glands (modifies the biochemistry of the stink glands. Production of quinones greatly reduced. The reservoirs of the stink glands contain a clear liquid and lumps of a black crystalline substance)
mt	mottled (like msg it modifies the biochemistry of the stink glands)
Mu	Multiple urogomphi (one or two additional urogomphi in larvae and adults)
rju	reduced juvenile urogomphi (paedomorphic urogomphi in adults reduced to small bristles next to the anal opening)
Tu	Tetraurogomphi (extra set of urogomphi; duplication of the genitalia in both sexes)
u	urogomphiless (one or both urogomphi missing, genital lobes may also be absent)
	T. confusum
em	emasculated (sex limited; male pupae lack genital lobes which result in imagos without aedeagi)
Hg	Horned gena (pair of horns arising from genoclypeal suture. The cranium is fragmented between the eyes)
msg	melanotic stink glands (modifies the biochemistry of the stink glands)
rju	reduced juvenile urogomphi (appears to be male limited. Expression variable from bristle-sized to rather large paedomorphic structures)

Table 11. Mutants affecting the wings in T. confusum

symbol	name of mutant and phenotypic effect
bld	blade elytra (elytra narrow and divergent, with a sharp point. Legs may be missing beyond the femurs. Epimera short or absent)
ble	blistered elytra (large blisters on one or both elytra)
cru	crumpled (split droopy elytra, reduced in size, and with rough surface)
depr	depressed (elytra pushed down behind the scutellum)
dj	disjoined (elytra diverge in both pupae and adults)
dre	droopy elytra (the elytra droop at the sides)
ele	elongated elytra (elytra extend well beyond the posterior end of the abdomen. May interfere with successful insemination)
nd	nude (elytra and membranous wings reduced
pel	pointed elytra-like (elytra mostly divergent and pointed)
ro	rough (pupae may have a blister on the elytra which is carried over into the adult stage. Adults with elytra warped or wrinkled)
sh	short elytra (about 2/3 the normal length)
sp	split (elytra short; may be divergent)
St	Striped (St males have white elytra, are sterile and die at an early age. St/+ young females have a white stripe in the middle of each elytra which becomes completely pigmented with age)
te	truncated elytra
tet	thickened elytral tips
thu	thumbed (elytra shorter by one abdominal segment, and sometimes divergent)
thu^S	thumbed (an allele of thu. When heterozygous promotes fast development)
we	warped elytra (elytra are raised and may be wavy)
wgl	wingless (pupa has wing and elytra buds which persist into the adult stage)
wspl-1	wide-split-1 (elytra widely divergent along their whole length)

Table 12. Homeotic mutants in T. confusum

symbol	name of mutant and phenotypic effect
apt	alate prothorax (in pupa and adult, the prothorax bears outgrowths which resemble the elytra)
Hg	Horned gena (horns arise in both sexes from the genoclypeal suture)
knp	knobby prothorax (may be allelic to apt)
lp	labiopedia (labial palps modified into legs similar to the forelegs in larvae, pupae and adults)
pas	pointed abodominal segments (all the abdominal segments acquire a medial anterior projection of the sternite, mimicking the appearance of the apparent first abdominal segment)

Table 13. Antennal mutants in T. confusum

Symbol	Name of mutant and phenotypic effect
fas-1	fused antennal segments-1 (fusions involve segments 7-8 and 9-10)
fas-2	fused antennal segments-2 (fusions involve segments 3-4 and 5-6)

Table 14. Mutants affecting body color in *T. confusum*

Symbol	Name of mutant and phenotypic effect
b	black (similar to b in *T. castaneum*)
e	ebony (similar to j in *T. castaneum*)
e-2	ebony-2 (similar to b)

Table 15. Eye color mutant in T. confusum

Symbol	Name of mutant and phenotypic effect
dpe	dirty pearl eye (similar to p in the pupa and the teneral adult. Older adult eyes are reddish with some black spots)
dpe^{fro}	frosted (allelic to dpe)
es	eyespot (dark red eye, becomes black with age)
es^{lt}	light eyespot (allelic to es. Ommatidia are lighter red)
lod	light ocular diaphragm
p	pearl (ocelli and ommatidia of compound eyes lack black pigment)
p^{r}	pearl-riboflavinless (smaller amounts of riboflavin than in p in larvae and pupae which decrease drastically in the adult stage)
r	red (identifiable in the pupa and adult)
r^{D}	red of Dawson (allelic to r. Identifiable during the first 10 weeks of adult life)
rby	ruby (dark red eyes darken with age, becoming black as in wild type)
rus	ruby spot (dark eye with a reddish spot in the middle)

Table 16. Mutants modifying eye shape in T. confusum

Symbol	Name of mutant and phenotypic effect
Rey	Reduced eye (some dorsal lobe ommatidia fail to form)
de	diminished eye (the eye is misshapen to a varying degree, ranging from a smooth faceted narrow area, similar to Be in T. castaneum to an eye of normal appearance but reduced in size)

Table 17. Mutants affecting legs in T. confusum

Symbol	Name of mutant and phenotypic effect
bf	bent femur (proximal third of femur is narrow and sharply bent)
btt	bent tibia (shorter leg due to double bent tibia)
dl	deformed legs (femur short and pear-shaped, or short and bent. One pair of the legs or one leg of the pair is affected. Tibia may be curved or tarsal segments and tibia may be missing)
lgl	legless (the legs, or parts of them, may turn white and then break off)
stl	stilted legs (fusion of antennal and tarsal segments. Femurs short, tibiae long and slender, fusions of tarsal segments and mainly of antennal segments 7-8 and 9-10)

Table 18. Mutants with pleiotropic effects in T. confusum.

Symbol	Name of mutant and phenotypic effect
aer	antennae and elytra reduced
ptll	prothoraxlesslike (similar to ptl in T. castaneum except that the labium is not affected in T. castaneum , but is small and droops in T. confusum).
Rey	Reduced eye (affects eye and body size)
stt	stunted (affects whole body. Most pronounced effect is in the shortening of the appendages: fusion of segments 7-8 of the antenna. Segments of the tarsi are also fused, more often in males than in females. Maxillary palpomeres are fused. Elytra are 1/2 the normal length, usually divergent and may develop blisters)
stu	stumpy (antennae, elytra and membranous wings and legs are affected)

Table 19. Mutants affecting body weight in Tribolium

Symbol	Name of mutant and phenotypic effect
	T. castaneum
Gi	Giant (doubles the weight of the normal beetles. Larvae and pupae are also larger)
mi	midget (similar to py in size and to pok in delayed pupation and divergence of the elytra. Larval weight at 14 days is smaller, and pupation time is one day longer than in py)
py	pygmy (reduces the size of the beetles to 2/3 the normal length and about half of the normal weight)
ty	tiny (as small as py)
	T. confusum
xl	extra large
Rey	Reduced eye (may decrease body size)
stt	stunted

TECHNICAL NOTE

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*Some untested ideas for faster sterilization of Tribolium medium.

Inserting an aluminum nail in potatoes reduces the baking time by half when placed in a kitchen oven at 400 degrees Fahrenheit. The metal transfers heat directly to the center, the last part cooked. Such nails or lengths of stainless steel wire could similarly reduce sterilization time for Tribolium medius at 50 degrees C. If the nails protrude well above the medium, they could be removed later with flamed forceps.

A microwave oven could be used for very rapid sterilization. Since a coffee cup of water boils in about two minutes or less, the time would have to be determined carefully for each model of oven to avoid the problems of caking and modification of the medium. Nails or lengths of wire should not be used, as they absorb energy.

In tropical regions where temperatures can reach 45-50 degrees Celsius, in summer, medium could be sterilized in a glass-covered box tilted to catch the direct rays of the sun. Time for sterilization would vary according to the season.

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