TRIBOLIUM INFORMATION BULLETIN

Volume 30

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EDITOR: A. SOKOLOFF

PROFESSOR EMERITUS

BIOLOGY DEPARTMENT

CALIFORNIA STATE UNIVERSITY

SAN BERNARDINO Ca. 92407

TRIBOLIUM INFORMATION BULLETIN

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Note

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ACKNOWLEDGMENTS

The editor is indebted to ALEXANDRA SOKOLOFF and ELAINE SOKOLOFF for assistance in the preparation and distribution of TIB 30.

ANNOUNCEMENT

As of August 31, 1990, I will retire from teaching. I will then acquire the title of Emeritus Professor at California State University, SAN bernardino. I plan to continue as Editor of the Tribolium Information Bulletin, since I appear in reasonably good health, I plan to continue as Editor of the Tribolium Information Bulletin for as long as I am able and as long as interest in this publication continues.

A. SOKOLOFF

STOCK LISTS

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.).

Stock Lists

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.

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) "

Stock Lists

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 VII,II Corvallis 1975
S
180. ap --antennapedia VIII Berkeley 1962
D
186. sq --squint VIII Chazy 1959
189. apt--alate prothorax IX Berkeley 1963
192. ptl--prothoraxless IX Chazy 1959
194. ppas--partially pointed abdominal sternites Berk. 1963
196. mas--missing abdominal sternites II Berkeley 1964
228. Dch--Dachs II San Bernardino 1976
230. fas-1--fused antennal segments-1 Chazy 1959
233. imp--incomplete mesothoracic projections
238. mxp--maxillopedia II berkeley 1965
240. Npp--Non-punctate prothorax, a phenodeviant
245. pec--pectinate
252. sc--scar Purdue
259. w--white Purdue
261. fas-8--fused antennal segments-8
271. Gi--Giant PIL
278. la--long abdomen PIL
280. Veracruz small
288. fas-9 fused antennal segments-9 San Bernardino, 1975
295. pd,p--paddle, pearl I, II
296. pd,p,b--paddle, pearl black I, II, III
297. sp,p--spotted, pearl I, II
299. py,i,p--pygmy, ivory, pearl I, II, II
301. p, au, lod--pearl, aureate, light ocular diaphragm II, III, III.
302. p, au, mc--pearl, aureate, microcephalic II, III, V
303. p,b--pearl, black (II, III)
304. p,au,lod,msg--pearl, aureate, light ocular diaphragm, melanotic stink glands (II, III, III, III)
306. p,b,pe--pearl, black, pointed elytra (II, III,?)
308. p,mc--pearl, microcephalic II, V
310. p,s--pearl, sooty II, IV
312. p,j,Npp--pearl, jet, Non-punctate prothorax II, V
313. p,apt,Mo--pearl, alate prothorax, Microphthalmic II, II, VI.
315. p,mas--pearl, missing abdominal segments II, II
316. p, knp--pearl, knobby prothorax II, II
317. p,aa--pearl, abbreviated appendages II, V
322. p,Fas-4,b--pearl, Fused antennal segments-4, black II, ?, III
415. mxp,s--maxillopedia, sooty II, IV

416. au, s--aureate, sooty III,IV
417. h, s--hazel, sooty III, IV
428. c, Npp--chestnut, Nonpunctate prothorax VII, ?
430. au,Npp--aureate, Nonpunctate prothorax III, ?
436. au,mc--aureate, microcephalic III, V
442. Df,s,Mo--Deformed, sooty, Microphthalmic ?, IV, VI
444. i,lod,Mo--ivory, light ocular diaphragm, Microphthalmic II, III, VI
445. i,ppas-ivory, partially pointed abdom. sternites II, ?
448. Chr,ap--Charcoal, antennapedia III, VIII
450. au,ble--aureate, blistered elytra III, VII
ELL Pk
454. p /p II
462. mas, mc--missing abdominal segments, microcephalic II,V
469. i,lod--ivory, light ocular diaphragm II,III
470. lod,rb--light ocular diaphragm, ruby III, ?
473. fas-6--fused antennal segments-6

V. Tribolium confusum

Wild type strains

1. Chicago	Park, 1955
2. Chicago	via Sokal, 1975
3. McGill	via McDonald
4. McGill	Stanley, 1958
5. New York	1961
6. Sacramento	
7. San Bernardino	1968
8. Yugoslavia	1975

Synthetic strains

1. Berkeley

Mutant strains

apt--alate prothorax I
apt,fas-2--alate prothorax, fused antennal segments-2
b-black III
b,cas,p--black, creased abdominal segments, pearl
b,lod,p--black, light ocular diaphragm, pearl
b,p--black, pearl
b,rus--black, ruby spot
b,rus,spl--black, ruby spot, split
b,twa--black, twisted abdomen
b-2--black-2
b-2/b McGill--synthetic black
bZ,rZ--black Zagreb, red Zagreb
(black strains from Carlisle, Pa., Chicago, Donner lab, Georgia, McGill, Sault Ste. Marie, Winnipeg and Yugoslavia)
b-Chicago/b McGill--synthetic black
b-Mcgill,fas--black, fused antennal segments
b-Mcgill,p--black, pearl

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

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

Stock Lists

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., 1975 Savannah, Ga., 1974.
Trogoderma variabile Ballion	Field collected, Mn., 1972.

Cucujidae

Oryzaephilus surinamensis (L)	Savannah, Georgia, 1975.
Oryzaephilus mercator (Fauvel)	Savannah, Georgia, 1984.
Cryptolestes pusillus (Schoenherr)	Manhattan Ka. 1967.
Cryptolestes ferrugineus (Stephens)	Unknown

Silvanidae

Ahasverus advena Waltl.	Field collected, Mn., 1984

Tenebrionidae

Cyaneus angustus (LeConte)	Winnipeg; 1974. Field collected, Mn., 1977
Tribolium castaneum (Herbst)	Corvallis, Ore. 1976.
Tribolium confusum duVal	Unknown *
Tenebrio molitor	Carolina Biological, 1984

Anobiidae

Lasioderma serricorne (Fab.)	Savannah, ga., 1975
Stegobium paniceum	Unknown *

Bostrichidae

Rhizopertha dominica (F.)	Manhattan, Ka.
Prostephanus truncatus (Horn)	Unknown *

Curculionidae

Sitophilus granarius (L.)	Unknown *
S. oryzae (L.)	Inknown *

B. Lepidoptera

Pyralidae

Plodia interpunctella (Hubner)	Manhattan, Ka., 1972

Gelechiidae

Sitotroga cerealella (Oliver)	Savannah, Ga., 1975

KRISTEN BERG

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
Plant Research Institute
Department of Agriculture and Rural Affairs

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
Fenitrothion 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
(No change--Ed).

Queensland Department of Primary Industries, Entomology Branch,
Indooroopilly, Queensland,
Australia

Coleoptera

	TYPE	ORIGIN
Carpophilus dimidiatus	Wild	Queensland
Dermestes maculatus	Wild	Queensland
Lasioderma serricorne	Wild	Queensland
Necrobia rufipes	Wild	Queensland
Oryzaephilus surinamensis		
VOS 48	insecticide susceptible	Victoria
QOS 42	fenitrothion resistant	Queensland
ZOS 73	fenitrothion resistant	Queensland

Stock Lists

	Type	Origin
Rhyzopertha dominica		
QRD 14	Insecticide susceptible	Queensland
QRD 2	multi-resistant	Queensland
QRD 63	multi-resistant	Queensland
Sitophilus oryzae		
LS 2	insecticide susceptible	Queensland
QSO 56	multi-resistant	Queensland
CSO 231	multi-resistant	W. Australia
Tribolium castaneum		
Wild type strains		
QTC 4	insecticide susceptible	Queensland
QTC 279	pyrethroid insecticide resistant	Queensland
QTC 285	multi-resistant, composite strain	Queensland
CTC 12	non-specific malathion resistant	Queensland
QTC 34	malathion soecific-resistant	Queensland
Mutant strains		
TC 65	pearl p	
TC 86	black b	
TC 179	antennapedia ap	
TC 113	sooty s	
TC 136	jet j	
TC 156	microphthalmic Mo	
TC 165	chestnut c	
LEPIDOPTERA		
Ephestia cautella	Wild	Queensland
Plodia interpunctella	Wild	New South Wales

Graham White, Senior Entomologist.

Stock Lists

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.).

CANADA

GUelph, Ontario.
University of Guelph
Dept. of Animal and Poultry Science

1. Wild type strains

   Tribolium castaneum Purdue, 1960
   Base population for quantitative genetics

2. Mutant strains

   pygmy py Purdue, 1960
   Base populations maintained with no artificial selection and minimum of inbreeding.

Zhang Lao

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

CHINA

Beijing, People's Republic of China
Beijing Agricultural University
Department of Animal Science

1. Wild Type Strains

Tribolium castaneum Base populations for Quantitative genetics.	Guelph, 1987

2. Mutant strains

pygmy py
Base populations maintained with no artificial selection and minimum of inbreeding.

Zhang Lao

Stock Lists

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

I. 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
5. Abbc	Synthetic, 1982
6. bbc	Synthetic, 1982

Mutant strains (originals)

7. antennapedia, (ap^{N} -VIII (1981)	Bogota, 1981
8. bifurcated antenna, ab-II (1979)	Bogota, 1979
9. black, b-III	Bogota, 1983
10. charcoal, chr-III	Bogota, 1981
11. chestnut eyes, oc- ?-	Bogota, 1984
12. disjuncted elytra, es- ?	Bogota. 1982
13. fused antennameres, af- ?	Bogota, 1980
14. glass legs, pv-?-	Bogota, 1980
15. ivory eyes, omf-I	Bogota, 1981
16. light eyes, op -?-	Bogota, 1985
17. miniature appendaged ma-I-	Bogota, 1981
18. narrow eye (oje) -?-	Bogota, 1980
19. red eyes or- ?-	Bogota, 1980
20. scars, ca -sc?-	Bogota, 1984
21. white eye, obl -IV-	Bogota, 1982

II. gnathocerus cornutus

1.Wild strain.	Apulo, (Cund.) Colombia

III. Oryzaephilus surinamensis

1. Wild strain	Chocolate from U.S.A.

Fernando Nunez del Castillo

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

Stock Lists

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

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
Lepidoptera	
Phycitidae	
Ephestia elutella (Hubner)	Wild
E. cautella (Walker)	Wild, brown mut. strain
E. kuhniella (Zeller	Wild
Mutant:	
b black wing mutant	
pl-1 white larval color strain	
pl-2 " " " "	
pl-9 red larval color strain	
pl-10 " " " "	
pl-11 Intermediate larval color strain	
pl-12 " " " "	

Stock Lists

pl-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. Rhyzopertha dominica	Miyazaki
11. Sitophilus oryzae	Okayama
12. S. zeamais	Okayama
13. Tenebrio molitor	Okayama
14. Tenebroides mauritanicus	Okayama
15. Tribolium castaneum	Miyazaki
16. T. confusum	Miyazaki
17. T. freemani	

HYMENOPTERA

1. anisopteromalus calandrae	Okayama
2. Chaetospila elegans	Okayama
Lariophagus distinguendus	Okayama

Toshiharu Yoshida

Stock Lists

INSTITUTE OF BIOLOGICAL SCIENCES
UNIVERSITY OF TSUKUBA
TSUKUBA, IBARAKI 305 JAPAN

COLEOPTERA
  Bruchidae
    Callosobruchus chinensis
      13 strains from various localities in Japan and abroad.
      1 black colored mutant derived from Shuzenji strain.
        cC Mainland China
        fC Fukushima, Japan
        hC Hirosaki, Japan
        $h_{1}C$ Hirosaki, Japan
        jC Kyoto, Japan, 1936
        mC Morioka, Japan
        nC Niigata, Japan, 1964
        pC Punjab, India
        sC_{bl} Shuzenji black mutant
        tC Tokyo (Nishigahara, Nat. Inst. Agr.), Japan
        $t_{a}C$ Tsukuba, Japan
        $t_{a2}C$ Tsukuba, Japan
        $t_{s}C$ Tsukuba, Japan
        yC Taisha, Japan

Callosobruchus maculatus
  12 strains from various localities in the world
  aQ U.S.A. (prob. Louisiana)
  bQ Burma
  cQ Fresno Lab., USDA, Calif. U.S.A.
  eQ
  fQ Thailand
  gQ
  iQ U.S.A. (dr. Mitchell's lab)
  kQ Kyoto, Japan
  mQ Kansas State Univ., Manhattan, KS, U.S.A.
  rQ
  sQ Savannah Lab., U.S.D.A., Georgia, U.S.A.
  tQ Tel Aviv, Isr. (Dept. Plant Prot., Stored Prod. Res. Lab.)
  yQ England (Dr. Creland's lab)
Zabrotes subfasciatus Africa
Callosobruchus analis United Kingdom
Callosobruchus phaseoli United Kingdom
Acanthoscelides obtectus California, U.S.A.

Curculionidae
  Sitophilus zeamais National Food Research Institute (Japan)
  Sitophilus oryzae " " " " "

Stock Lists

HYMENOPTERA

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

Koichi 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, U.S.A.	1964
3.	edinburgh 1	Edinburgh, Scotland	1970
4.	Edinburgh 2	" "	"
5.	Campanario	Campanario, Spain	1973
6.	Coronada	La Coronoda "	1976
7.	Andujar	Andujar, "	1975
8.	Jerez	Jerez, "	1975
9.	Osuna	Osuna, "	1975
10.	Carpio	Carpio, "	1975
11.	Jafo	Jafo, Israel	1975
12.	Beer-Sheba	Beer-Sheba, Israel	1975

B. mutant strains

13.	Black Purdue	Purdue, U.S.A.	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.	BFII	" "	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	" "	38

36. ST-II " " 38
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 a, 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,	1964
53.	rose rs	Purdue,	1964
54.	ruby rb ?	Purdue,	1964
55.	short elytra sh VIII		
56.	squint sq VIII	Purdue.	1964
57.	white w ?	Purdue	
58.	wine r^w I	Purdue,	1968
59.	eye mutant ?	Madrid,	1967
60.	maroon m ?	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	
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 II	Sokoloff,	1968

Ma. C. Fuentes

MEXICO

INstituto Nacional de Investigaciones Agricolas
Centro de Investigaciones Agricolas del Norte Centro
Pabellon, Aguascalientes, Zacatecas

Prostephanus truncatus--wild type strain

M.C. Mario Ramirez Martinez

POLAND

POLISH ACADEMY OF SCIENCES, INSTITUTE OF ECOLOGY,
DZIEKANOW LESNY, 05092, LOMIANKI, POLAND

Acanthoscelides obtectus Say--Wild type, Poland

Tribolium castaneum Hbst.
- Wild strain from San Bernardino via Freiburg
- cI genetic strain from Chicago
- cII " " " "
- cIII " " " "
- cIV " " " "
- sooty (s) from San Bernardino via Freiburg
- pearl (p) " " " " "
- pygmy, paddle, platinum (py,pd,ptl) from San Bernardino via Chicago

Tribolium confusum

- Wild strain from San Bernardino via Freiburg
- bI genetic strain from Chicago
- bII " " " "
- bIII " " " "
- ebony-2 e-2 from San Bernardino via Freiburg

Tadeusz Prus

Stock Lists

PEOPLE'S REPUBLIC OF CHINA
BEIJING
BEIJING AGRICULTURAL UNIVERSITY
DEPARTMENT OF ANIMAL SCIENCE

Tribolium castaneum

Wild type strains

1.	Base populations for quantitative studies	Guelph, 1957.
2.	Inbreeding line (full sib-mating)	Beijing, 1988
3.	Wu line (local line	Beijing, 1988

Mutant strains: py

1. Base population maintained with no artificial selection and minimum of inbreeding
2. Inbreeding line (full sib mating) Beijing 1988

Zhang Lao

UNITED KINGDOM

ADAS CENTRAL SCIENCE LABORATORY
MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
LONDON ROAD
SLOUGH, BERKS, U.K.
SL3 7HJ TEL (0753) 34626 Fax (0753 824058

Insects mentioned below are bred in controlled environmental conditions and, as far as possible, free from disease. All new stocks pass through a quarantine procedure before acceptance into the main insectaries. This list was last updated in November 1988. The country of origin and year of receipt at this laboratory are shown against strains, where this information is known. For some of the older strains, such information is not known. Please note thatz some strains do not have a name, especially if only one strain of a species is held. Where more than five strains of a species are held, full details are not given. (However, full details of all mutant strains held are given). Please write to me for further details on any aspect of this list and with any requests for specimens. The latter will be met where sufficient are available, but a charge may have to be made.

Monica O'Donnell (Mrs.)

Species	Strain	Country of origin	Year received at Lab.
COLEOPTERA			
Ahasverus advena (Waltl)	Insectary	W. Africa	1956
Alphitobius diaperinus (Panz)	Insectary		
	Goose's foot	Britain	1983
	Droxford	Britain	1984
	35	Britain	1987
Anthrenocerus australis (HopeO	Insectary	Britain	1933
Anthrenus flavipes (LeC.)	Insectary		
A. picturatus Hintoni (Mroczkowski)	Insectary	U.S.S.R.	
A. sarnicus (Mroczkowski)	Insectary		
A. verbasci (L.)	Insectary	Britain	1951

Attagenus brunneus Falderman	Insectary	Spain	
A. cyphonoides Reitter		U.S.S.R.	1976
A. fasciatus cinnamomeus (Roth)	Insectary	Botswana	1965
A. fasciatus fasciatus (Thunberg)	Insectary	Botswana	1972
A. insidiosus Halstead	Insectary	Kenya	
A. pellio (L.)	Insectary	Britain	
A. rufiventris Pic	Insectary	Botswana	1970
A. smirnovi Zhantier	Insectary	Kenya	1962
A. unicolor japonicus Reitter	Insectary	Japan	1956
A. unicolor japonicus Reitter (Synonym A. unicolor canadensis Casey	Insectary	N. U.S.A.	1980
A. unicolor simulans Solsky	Insectary	U.S.S.R.	1976
A. unicolor unicolor (Brahm) (=megatoma (F.) =piceus (Olivier)			
A. woodroffi	Finland		1965
Halstead & Green	Sweden		1978
Carpophilus dimidiatus (F.)	Insectary	U.S.A.	
C. hemipterus (L.)	Insectary		
Coelopalorus foveicollis (Blair)	Trinidad		
Cryptolestes capensis (Waltl)	Insectary		
C. ferrugineus (Steph.)	9 strains from 2 countries held, many differing in their susceptibility to pesticides		
C. pusilloides (Steel and Howe)	Canada		
C. pusillus (Scho.)			
C. pusillus fuscus Lefkovitch	Trinidad		
C. turcicus (Grouv.)			
C. ugandae Steel and Howe		E. Africa	1954
Dermestes ater Deg.		Britain	1953
D. frischii Kug.		Nigeria	
D. haemorrhoidalis Kuster		Britain	
D. lardarius		Britain	
D. maculatus Deg.		Bangladesh	1975
D. peruvianus Castelnau		Britain	1961
Gibbium aequinoctiale (Boield.)		Britain	1937

Gnatocerus cornutus (F.)			
G. maxillosus (F.)			
Lasioderma serricorne (F.)	Insectary		
Latheticus oryzae Waterh.	Insectary		
Mezium affine Boield.	Insectary	Britain	
M. americanum (Lap.)	Insectary		
Niptus hololeucus (Fald.	Insectary		
Oryzaephilus acuminatus Halstead	Insectary		
O. mercator (Fuv.)	Insectary		
	Senegal	Senegal	1979
	O-871	Cyprus	1979
O. surinamensis (L.)	52 strains from 11 countries held, many differing in their susceptibility to pesticides		
Palorus ratzeburgi (Wissm.)	Insectary		
Palorus subdepressus (Woll.)			
Pseudeurostus hilleri (Reitt.)	Insectary	Britain	1940
Ptinus clavipes Panz.		Britain	1954
P. exulans Er.		Britain	
P. pusillus Sturm	Insectary		
P. sexpunctatus Panz.	Insectary		
P. tectus Boield.	Insectary A		
	Insectary B	Britain	1960
	Wild	Britain	1975
Rhyzopertha dominica (F.)	8 strains from 5 countries held, many differing in their susceptibility to pesticides		
Sitophagus hololeptoides (Cast.)	Insectary	Trinidad	1972
Sitophilus granarius (L.)	15 strians from 5 countries held, many differing in their susceptibility to pesticides		
S. oryzae (L.)	7 strains from 6 countries held, many differing in their susceptibility to pesticides		
S. zeamais Motsch.	Insectary		
	153	Guatemala	1972
	912	Kuwait	1972
	US	USA	1976
	PS-60	Britain	1984

Sphaericus gibboides (Boield.)	Insectary	Britain	1976
Stegobium paniceum (L.)	Insectary		
Stethomezium squamosum Hint.	Insectary	Britain	
Tenebrio molitor L.	Insectary		
T. molitor F.	Insectary		
Tipnus unicolor (P. & M.)	Insectary	Kenya	
Tribolium anaphe Hint.	Insectary	Nigeria	
T. audax Halstead	Insectary	Canada	
T. brevicornis LeC	Insectary	USA	
T. castaneum (Herbst)	7 strains from 5 countries held, many differing in their susceptibility to pesdticides		
T. confusum J. du V.	Insectary		
	W-44		
	PS-108	Britain	1983
T. destructor Uytt.	Ethiopia	Ethiopia	1968
	Denmark	Denmark	1968
T. freemani Hinton	Insectary	Japan	1980
T. madens (Charp.)	Insectary	Yugoslavia	
Trigonogenius globulus Sol.	Insectary	Ireland	
T. particularis Pic	Insectary	Kenya	
Trogoderma angustum (Solier)	Insectary	Germany	1975
T. anthrenoides (Sharp)	Insectary	USA	
T. glabrum (Herbst)	Insectary	USA	
T. granarium Everts	11 strains from 7 countries held.		
T. grassmanii Beal	Insectary	USA	1976
T. inclusum LeC	Insectary		
T. irroratum Reitt.	Insectary	Egypt	
T. sternale plagifer Casey	Insectary	USA	
T. varium Matsumura and Yohoyama	Insectary	Korea	1970
T. variabile Ballion	Insectary	USA	
Typhaea stercorea (L.)	Somerset	Britain	
	Datchet	Britain	1980

DICTYOPTERA

Blatta orientalis L.	Insectary		
	W. Middlesex	Britain	1986
Blattella germanica (L.)			
Periplaneta americana (L.)			

Stock Lists

DIPTERA

Musca domestica L.	6 strains from 2 countries held, several other strains also held, but on a short term basis		

HYMENOPTERA

Monomorium pharaonis (L.)		Britain	1953

LEPIDOPTERA

Endrosis sarcitrella (L.)	Reading	Britain	1986
Ephestia cautella (Walker)	Insectary	Cyprus	1969
E. elutella (Hubner)	Insectary		
	Milwall 8F	Britain	1969
E. Kuehniella Zell.	Insectary	Britain	1949
	Southampton	Britain	1953
	Harlescott	Britain	1982
	Rhydymwyn	Britain	1988
Galleria mellonella (L.)	Insectary A		
	Insectary B	USA	
Plodia interpunctella Hubner	9 strains from 9 countries held		
Sitotroga cerealella (Oliv.)	A68	Nepal	1972
	S623	USA	1972

PSOCOPTERA

Lepinotus patruelis Pearman		Britain	
Liposcelis Bostrychophilus		Britain	1949
L. subfuscus (Broadhead)			
Trogium pulsatorium		Britain	

MUTANT STOCKS

Species	Mutation	Strain/s mutation/s arose in	Country of origin
COLEOPTERA			
Carpophilus dimidiatus (F.)	Pearl eye		
Cryptolestes turcicus (Grouv.)	Red eye		
Dermestes maculatus Deg.	Pearl-eye		
	Black/Brown		Australia
Lasioderma serricorne (F.)	Black		USA
Oryzaephilus mercator (Fauv)	Pearl eye X (pe)	0-779	Pacific Isles
O. surinamensis (L.)	Clear eye (cc)	00757	
	Dark body (dd)	484 Square	India
	Speckled eye	484 Diamond	India
	L.O.D. (ss,ll)	484 Diamond	India
	Transparent eye (tt)	01061	Britain
	Clear eye, dark body (cc, dd)		
	Speckled eye, dark body (ss,dd)		
	Transparent eye, dark body (tt, dd)		
Rhyzopertha dominica (F.	Black		
Tribolium castaneum (Herbst)	Black		
LEPIDOPTERA			
Ephestia cautella (Walker)	Yellow eye	Florida	USA
	Black eye	Insectary	Cyprus
	Diapause	x Florida	USA
Ephestia elutella (Hubner)	White eye		
Sitotroga cerealella (oliv.)	Pearl eye	A68	Nepal
	Red eye	A68	Nepal

Monica O'Donnell (Mrs.)

STORAGE DEPARTMENT
NATURAL RESOURCES INSTITUTE
CHATHAM, UNITED KINGDOM

We have the following wild type strains of T. castaneum vary in susceptibility to insecticides and fumigants.

Set-up date	Ref. No.	Origin
7-88	Ref.	MAFF Slough, UK
5-85	3	Landhi, Pakistan
12-85	11	Kohinoor, Karachi, Pakistan
5-86	14	Cilacap, Indonesia
3-87	26	Pakistan
3-87	28	Karachi, Pakistan
11-87	36	Mali
2-88	39	NAPHIRE, Philippines
2-88	40	Naphire, Philippines
6-88	42	Cochin, India
2-88	43	Hyderabad, India
7-89	48	Narahenpita, Sri Lanka
8-88	50	Botswana (ex USA)
2-89	51	Georgetown, Guyana
12-88	52	Port Sudan, Sudan
2-89	53	Dessie, Ethiopia
3-89	55	Zimbabwe
3-89	56	Nairobi, Kenya
3-89	58	Mombassa, Kenya
3-89	59	Bamako, Bali
3-89	60	Mombassa, Kenya
11-89	66	Java, Indonesia
12-89	67a/b	Ex Thailand to Dakar, W. Africa

D.P.REES

SLOUGH, BERKS., U.K.
OVERSEAS DEVELOPMENT NATURAL RESOURCES INSTITUTE, SLOUGH DEPT.
OVERSEAS DEVELOPMENT ADMINISTRATION

PEST BIOLOGY AND INSPECTION SECTION

All stocks are maintained at 27 C and 70% R.H. The stocks listed 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.

1. Wild type strains
   A. COLEOPTERA

	Bruchidae	
1.	Acanthoscelides obtectus	a. Swaziland
		b. Colombia (6 strains)
		c. Turkey
		d. Colombia-CIAT
2.	Callosobruchus analis	a. ex MAFF Lab., Slough
3.	C. chinensis	a. Kenya
		b. Indonesia
4.	C. maculatus	a. Brazil
		b. Yemen, A.R.
		c. Nigeria
		d. Uganda
		e. Indonesia
5.	C. rhodesianus	a. Zimbabwe
6.	Caryedon serratus	a. unknown
		b. India
	Cucujidae	
7.	Cryptolestes ferrugineus	a. unknown
	Bostrichidae	
8.	Dinoderus distinctus	a. Tanzania
9.	D. minutus	a. Indonesia
10.	D. porcellus	a. Togo
	Tenbrionidae	
11.	Gnatocerus maxillosus	a. Tanzania
	Anobiidae	
12.	Lasioderma serricorne	a. unknown
	Lophocateridae	
13.	Lophocateres pusillus	a. Philippines
	Bostrichidae	
14.	Prostephanus truncatus	a. Mexico
		b. Tanzania (2 strains)
		c. Togo
		d. Costa Rica
15.	Rhyzopertha dominica	a. ex MAFF Lab. Slough

	b. Mali	
Curculionidae		
16. Sitophilus oryzae		
i. Normal strains	a. Indonesia	
	B. Tanzania	
ii. Pulse-feeding strains	a. Burma	(2 strains)
	b. Peru	
	c. Trinidad	(2 strains)
17. S. zeamais	a. Tanzania	
	b. Indonesia	
	c. Mexico	(2 strains)
	d. Ex MAFF Lab. Slough	
Histeridae		
18. Tretriosoma nigrescens	a. Mexico	
	b. Costa Rica	
Tenebrionidae		
19. Tribolium castaneum	a. Tanzania	
	b. Unknown	
	c. Mali	
Bruchidae		
20. Zabrotes subfasciatus	a. Colombia	(4 strains)
	b. Uganda	

B. LEPIDOPTERA

Galleriinae	
1. Corcyra cephalonica	a. Malawi
Phycitinae	
2. Ephestia cautella	a. Ethiopia
	b. MAFF Lab. Slough
3. E. elutella	a. Unknown
4. Plodia interpunctella	a. Unknown
Gelechiidae	
5. Sitotroga cerealella	a. Sudan

CHEMICAL CONTROL SECTION

Stocks of some major pests are maintained, under selection pressure with insecticide where necessary, in order to eanble 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 programmes

Wild type strains

A. COLEOPTERA

Cucujidae	
21. Cryptolestes sp.	a. Ethiopia
Dermestidae	
22. Dermestes ater	a. Ex MAFF Lab. Slough
23. D. frischii	a. Ex MAFF Lab. Slough
24. D. maculatus	a. Malawi
25. D. carnivorus	a. Indonesia
Curculionidae	
26. Sitophilus oryzae	
Insecticide-susceptible reference strain	a. Ex MAFF Lab. Slough
Malathion- and lindane-resistant strain (A76)	b. Ex MAFF Lab. Slough
Strains tested for phosphine resistance	c. Bhutan d. Nepal e. Pakistan (2 strains) f. Tunisia g. Brazil h. Tanzania i. Philippines j. Morocco
27. S. granarius	a. U.K. b. Cyprus
28. S. zeamais	a. Unknown
Strains tested for phosphine resistance	b. Ghana c. Zimbabwe d. Burma e. Thailand
Tenebrionidae	
Tribolium castaneum	
Multiple insecticide-resistant strain (CTC 12)	a. australia
Malathion-specific resistant strain (Kana C)	b. Nigeria
Insecticide-susceptible reference strain	c. Ex MAFF Lab. Slough
Phosphine resistant strains	d. Nepal e. Pakistan (8 strains) f. Sri Lanka

	g. Ethiopia (2 strains)
	h. Liberia
	i. Mali (5 strains)
	j. Zimbabwe (2 strains
	k. Ghana
	l. Philippines (2 ")
	m. India (7 strains)
	n. Tunisia
	o. Uganda
	p. Indonesia(6 strains)
	q. Cyprus (3 strains)
	r. Tanzania
	s. Brazil
Bostrichidae	
30. Prostephanus truncatus	As pest biology
Dinoderus sp.	a. Jamaica
Rhyzopertha dominica	
Phosphine resistnat strains	a. Nepal
	b. Pakistan (2 strains)
	c. Sri Lanka(2 strains)
	d. Mali
	e. Indonesia
	f. Ethiopia
	g. Morocco
	h. Brazil
Silvanidae	
33. Oryzaephilus surinamensis	a. Sri Lanka
Phosphine resistant strains	b. Ethiopia
Histeridae	
34. Teretriosoma nigrescens	As Pest Biology

Dr. Chris P. Haines

RESEARCH, TEACHING AND TECHNICAL NOTES

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*A simple technique for minimizing suicide in *Tribolium*

All species of *Tribolium* available in the laboratory secrete quinones which they store in the reservoirs of stink glands located in the prothorax and in the posterior portion of the abdomen. Some species of *Tribolium* secrete greater quantities of quinones per unit body weight than other species. For example, *T. castaneum,* weighing about 2.3 mg secretes 39,5 +3.43 ug quinones (Q) and 2.38 + 0.25 hydroquinones (HQ), while T. confusum, weighing about 2.5 mg secretes 33.08 + 2.62 ug HQ and 2.72 + 0.2 ug HQ, and T. brevicornis, weighing 7.5 mg on the average produces 2,25 + 28.72 ug Q and 15.26 + 1.04 ug HQ. (For further details see Table 15.6 in Sokoloff 1975).

Previous observations on *T. castaneum* and *T. confusum* have shown that when these beetles are taken out of the flour and examined under the dissecting microscope without etherization they will release a liquid when they are poked or squeezed with forceps This liquid has the odor of quinones. On occasion, if the contents of the various stadia of a culture are placed in the etherizer, the ether fumes may cause the beetles to release quinones. The effect of these secretions is evident on the eggs and the immature stadia and the teneral adults: these change in color from white or tan, acquiring a pinkish or purplish color. The eggs usually fail to hatch, and the larvae, pupae and teneral adults may also die depending on the concentration of the quinones. If the exposure is only slight, the parts affected may become black and necrotic, and the imagoes emerging from them may be highly deformed: the antennae may be completely or partially missing, and the distal segments of the legs may be missing.

If the adults and other stages of development are taken out of the flour and placed in an empty vial for a period of time, the beetles may be found dead or dying. It is assumed that if there are many adults, some may become irritated, release quinones, and because the quinones are denser than air, the quinones will cause their death. (The beetles will show some crystallization of the quinones on their rear ends, and the vial will definitely have the odor of quinones). There is some species differences in this suicidal behavior: *T. castaneum* is least likely while *T. confusum* is more likely to commit suicide in this manner, judging from the number of vials in which death of beetles has occurred.

With the availability of *T. freemani* for reasearch, we can add another species which will also commit suicide through the release of quinones. This species has not been investigated in regard to the amounts of quinones per unit body weight, but when the contents of a T. freemani culture are sifted and placed in a soup dish, the adults will release their quinones, and this release becomes evident by the behavior of the larvae, which begin to wiggle violently in response to the presence of these chemicals, and the odor of quinones becomes very evident if the contents of the soup dish are examined under the dissecting microscope.

During the course of an experiment to induce mutations through the use of EMS we have routinely isolated 100 males in an incubator maintained at 30 C. for 24 hours in an empty vial before they are fed a solution of sucrose mixed with a small amount of EMS. This procedure has been on the whole successful. The majority of these 100 male samples have survived for this period without mishap. However, a small number of samples was lost because of the beetles' release of quinones resulting in the death of all beetles. We attempted to reduce the incidence of this phenomenon by placing 50 males in each of two vials, thus reducing the density. This procedure improved the situation somewhat, but in some cases the beetles in one or both of these vials still committed suicide.

We then tried placing the container upside down in the incubator on the assumption that the slippery surface of glass vials caused some stimulation to the beetles to release their quinones. By placing the beetles on the coarse surface of a paper towel or a piece of Kimwipe, the beetles apparently feel more secure, and they are not as prone to release their quinones.

One more word on this subject. If you are scoring beetles from single pair matings, it is better to sift, etherize and count the contents of each vial separately. By sifting the contents of many vials in a single operation before etherizing and counting, one risks the possibility that the adults may become irritated at other adults or larvae and release quinones. And since a mutation may manifest itself in a single beetle and it may not occur for a long time, why risk the loss of this single individual through their exposure to quinones?

REFERENCES CITED

Sokoloff, A. The biology of Tribolium with special Emphasis on Genetic Aspects. Clarendon Press, Oxford

O'DELL, M., PAULUS, L. and GRIMNES, K.
Dept of Biology
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*Preliminary Characterization of the Male Accessory Reproductive Glands of Tribolium brevicornis (Coleoptera: Tenebrionidae)

Introduction

The contribution of reproductive glands other than the testes or the ovaries to the process of insect reproduction has often been overlooked (Leopold,1976; Happ,1984). This is true for the tenebrionid beetles, where the morphology and biochemistry of accessory reproductive glands have not been extensively studied, except for Tenebrio molitor, the mealworm beetle. Murad and Ahmad (1977) reported on a histological study of the accessory glands of Tribolium castaneum. We became interested in examining the reproductive accessory complex of Tribolium brevicornis, and comparing it to the complex of T. castaneum and to Tenebrio molitor.

Materials and Methods

Colonies of T. brevicornis were raised in petri dishes of white flour at a constant temperature of 32°C. Pupae were collected by sifting the media (US Standard 14 sieve) and were sexed by examination of the developing external genitalia. Upon eclosion to the adult stage, the animals were isolated and maintained at 32°C. For histological studies, 8-10 day adult glands were dissected in phosphate-buffered saline (PBS), fixed in 3% gluteraldehyde, embedded in Paraplast and sectioned at 7µm. Sections were stained in hematoxylin and eosin or Mallory's trichrome (Pearse,1968). Estimates of gland sizes were made using an ocular micrometer. For whole mount age studies, reproductive accessory gland complexes were dissected in PBS at 0, 2, 4, 6, and 8 days after eclosion. Glands were stained in 0.3% Oil Red O (ORO) in 70% ethanol or in 0.5% Sudan Black B in 70% ethanol overnight and destained in 30% ethanol.

Results and Discussion

The reproductive accessory gland complex of T. brevicornis consists of two sets of paired glands which are located at the junction between the seminal vesicles and the ejaculatory duct (Figure 1). Each gland is roughly circular in cross section, with a single layer of secretory epithelium surrounded by a thin muscular coat. Secretory material was observed in the lumen of both glands.

One set of glands, the tubular accessory glands (or TAGs) are long and thin, with uniform thickness throughout their length. The mean cell height for TAG secretory epithelium was 19.8 ± 0.5µm (n=10), with a lumen of about 40µm, giving the entire gland a width of 80µm. No differences between cells were detected with either hematoxylin or Mallory's trichrome, indicating a single, uniform cell type is present in the TAG.

The second pair of glands, the pear-shaped accessory glands (PAGs), possess a thickened wall that bulges outward at the terminus of the gland. A representative PAG had a mean length of 584.3 ± 2.7µm (n=7), with a mean width of 223.3 ± 1.3µm (n=23), and mean depth of 200.8 ± 1.3µm (n= 18). The secretory epithelium was composed of long thin cells (mean height 97.0 ± 1.6μm, n=9), surrounding a small lumen (about 20μm). Four distinct cell types were detected through staining of the mature gland with Mallory's trichrome and hematoxylin.

Intact adult glands stained with Oil Red O (ORO) or Sudan black also showed regional specificity of staining occurred in the PAGs but not the TAGs. Age-related trends in staining pattern were also seen. In the PAGs of newly eclosed adults, a small area of cells along the inner surface took up ORO, but not Sudan black. The staining in this area increased in size and intensity until day 2 of adult life. By day 4, the cap (terminal area) of each PAG had stained intensely with both ORO and Sudan black. In the mature (8 day) glands, an additional cell type was detected when cells on the shoulder of the gland (near the seminal vesicle attachment site) stained intensely with ORO, but not with Sudan black. The remainder of the gland (body) never accumulated either stain.

Conclusions

The reproductive accessory gland complex of T. brevicornis is quite similar to that of Tribolium castaneum and Tenebrio molitor. All three species possess two sets of paired glands, with one set generally long, thin and uniform in cell type, and the second gland with a thicker epithelium containing regionally distinct cell types. For both T. brevicornis and T. molitor, developmental changes occurred in the second gland, although in Tenebrio up to eight cell types have been detected (Dailey, et. al.,1980).

The biochemical changes which result in differential staining of cell types are still unknown and will be the subject of further investigation. The fact that T. brevicornis is one of the larger Tribolium species will be helpful in that regard.

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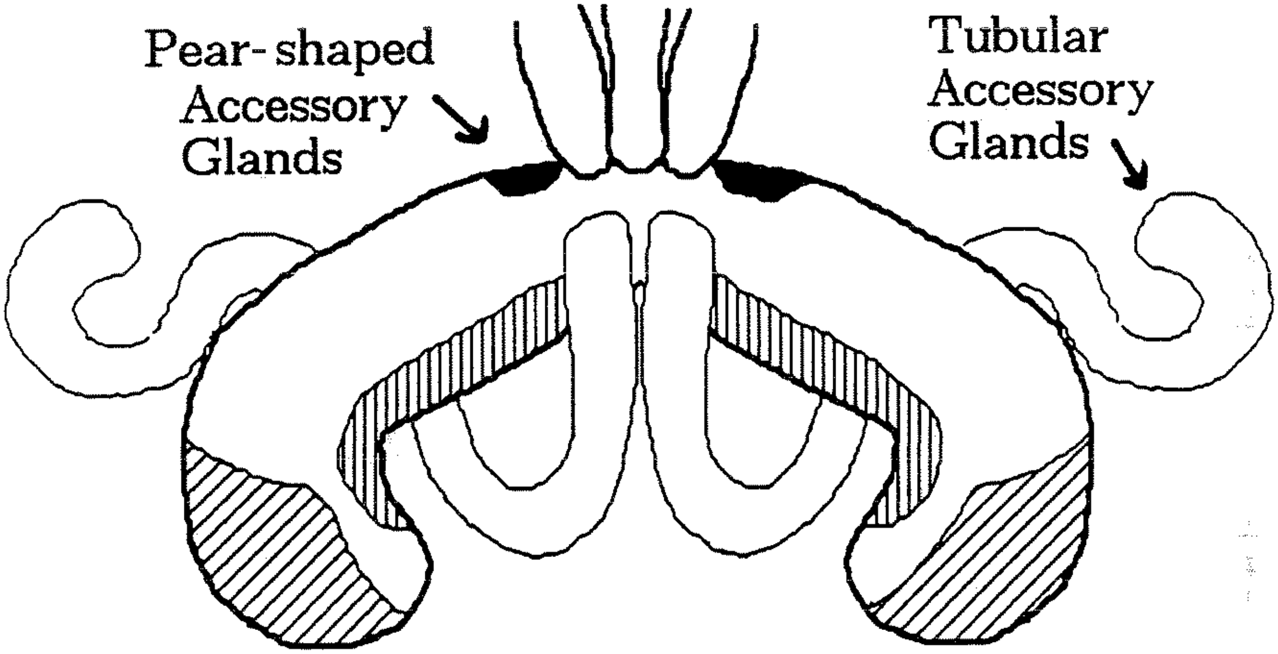

Figure 1. Tribolium brevicornis accessory glands (cell types indicated)

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* Thermal Requirements for Development of Stored-Product Insects.

INTRODUCTION

Predicting distribution and abundance of stored-product insects is essential for establishing effective control or management strategies of the pests. Climatic factors are often postulated to mainly determine the distribution and abundance of stored-product insects (Freeman, 1962; Sinha, 1974; Banks, 1977), as is the case with insects in general (e.g. Uvarov, 1931; Andrewartha and Birch, 1954). Messenger (1959) suggested that the theory of thermal constant is useful to estimate potential distribution and abundance of insects. The theory presumes a hyperbolic relationship between developmental period and temperature (Peairs, 1914; Bodenheimer, 1926):

$$y(t-a) = K,$$

where y is the time required for complete development of an organism stage at temperature t, a is threshold temperature above which the organism of the stage can develop, and K is thermal constant in day-degree. The model has some limitations due to its simplicity (e.g. Wagner et al., 1984), but may be also convenient for its simplicity when we compare temperature dependent development of various insects . The model includes only two parameters, each of which has a biological meaning. Howe (1965) listed minimum temperatures for the development of 53 stored-product insects but they do not correspond to the threshold temperature.

METHODS

The thermal constant (K) and the threshold temperature (a) for the development from egg deposition to adult emergence of 58 stored-product insect species including a predator and parasitoids were estimated by fitting a linear regression line to the temperature against reciprocal of developmental period (developmental rate, $1/y$) data from literatures. When the data points deviated from the regression line at low or high temperature ranges, they were omitted from the analysis. The number of data and temperature range analyzed are shown in Table 1. Standard error of K and a were estimated by the equations proposed by Campbell et al. (1974).

RESULTS

The results are summarized in Table 1.

H. pseudspretella had the largest thermal constant K and the lowest threshold temperature a. Another oechophorid *E. sarcitella* had also a relatively large K. *E. kuhniella* had the largest K and lowest a among the pyralid moths, although the figures of K varied with strain. These species occur in temperate regions. While a Mediterranean or a tropical moth species, *E. calidella* and *C. cephalonica* had a smaller K and higher a.

Among coleopterous species, ptinid species had a large K and low a with the exception of *P. pusillus*. While, K's of *L. oryzae* and *O. surinamensis* were small and some figures of K were less than

300 day-degree. Several cucujid species had also a small *K*. *a*'s of tenebrionid species were higher than 15°C except for those of *T. destructor* and *P. laesicollis*. Particularly *L. oryzae* which prefers hot climate (Freeman, 1962), had the highest *a*, which was higher than 20°C.

Braconid species required much smaller heat to complete development, but ichneumonid *V. canescens* required heat more than twice as much as the braconids.

Lepidopterous species had the largest mean *K* (774.9 ± 381.0, mean ± s.d. based on the data measured at an optimal condition for each species and those of males when the data of both sexes were available), followed by Coleoptera (502.3 ± 179.7) and predator and parasitoid (203.1 ± 86.2), although the means had large variations. While, mean *a* of Lepidoptera (10.7 ± 3.1) was lower than that of Coleoptera (14.3 ± 3.1) and *a*'s of predator and parasitoid ranged 10.5-16.3°C.

DISCUSSION

K and *a* differ depending on strains of a species. There are two distinctly different strains in *E. kuhniella*: a strain with a larger thermal requirement and a strain with a smaller thermal requirement. Payne (1934) reported that there were at least two strains of *E. kuhniella*, a fast development strain and a slow one and all moths obtained in Germany belonged to the slow strain and those from the United States contained both strains. The strain of Jacob and Cox (1977) corresponds to the slow strain and that of Imura (1986) to the fast strain. The slow strains have a lower *a* than the fast ones. A similar strain difference in *K* is also observed in *L. oryzae*, in which ,however, the difference in *a* is not significant.

Relative humidity or moisture content of medium alters *K*. With the exception of *L. oryzae* and *P. truncatus* which are tolerant of dry condition, the drier the rearing condition, the larger the *K* of the insects. Insects possibly require more energy to maintain body fluid at drier condition. This must be critical particularly for stored-product insects which rely on dry foods. However these condition may not basically affect *a* of stored-product insects, with the exception of *C. chinensis* in which *a* seems to decrease with humidity reduction.

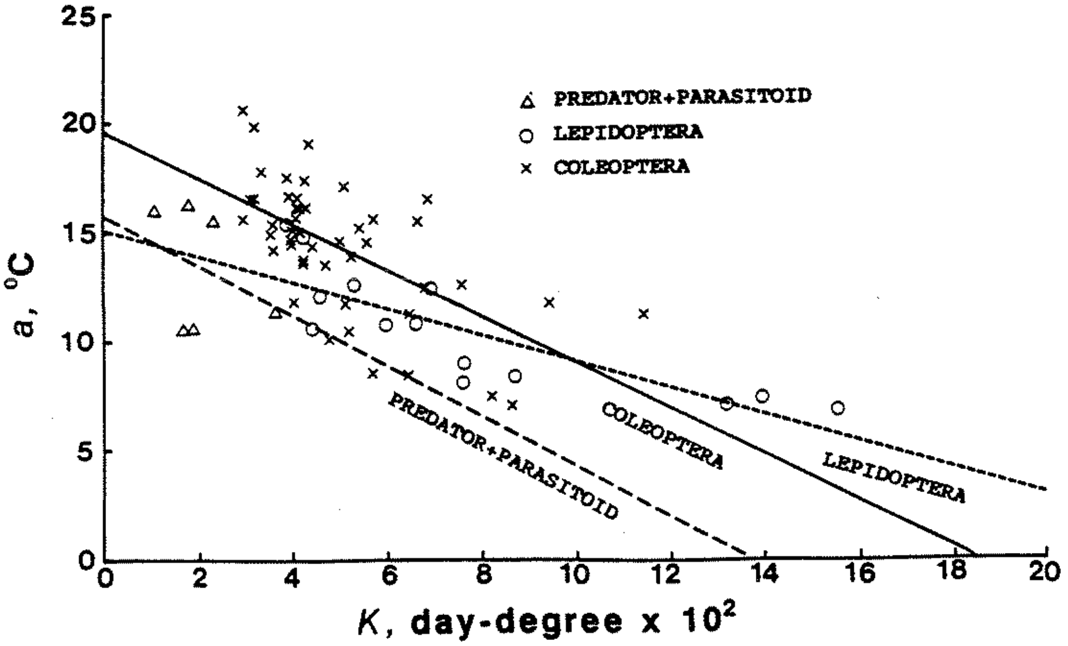

Fig. 1. Relationship between *a* and *K*. Lines are linear regression lines fitted to the data for 3 insect groups, Lepidoptera, Coleoptera, and predator and parasitoid.

K depends on diet. *O. surinamensis* had much smaller K on oats than on walnuts. Insects possibly require more heat on less efficient or nutritious media. The fact that predator and parasitoids have a smaller K than other species may also reflect a nutritional difference between sarcophagy and phytophagy. The production efficiency of carnivores is significantly higher than herbivores in insects (Hunphreys, 1979). In addition, Hagstrum and Milliken (1988) stated that moisture and diet seem to have more significant effect on the development of insects around optimal temperature for their development.

Females require more heat to complete development than males. Production of more costly gamete, eggs by females must be responsible for their larger K. a, however, dose not fundamentally differ with sexes.

The results reveal that species or strains of warmer regions generally have smaller K and higher a than those of cooler regions, although there are discrepancies for some species. There are statistically significant negative correlations ($p < 0.01$) between K and a in Lepidoptera ($r = -0.836$, $a = -0.006K + 15.1$) and Coleoptera ($r = -0.621$, $a = -0.011K + 19.6$) (Fig. 1), as Utida (1957) suggested. This relationship is anticipated, because one parameter is a function of the other: $a = -d \cdot K$, where d is y-intercept of the regression line fitted to the developmental rate against temperature data used for estimation of K and a. Consequently, y-intercept, d represents the slope of a against K regression line. The smaller r for Coleoptera is due to inclusion of species from various families. Fig. 2 shows the regression lines of two families of Coleoptera, Tenebrionidae and Cucujidae. Regression equation for Tenebrionidae is $a = -0.013K + 22.9$ ($r = -0.848^{**}$) and that for Cucujidae is $a = -0.013K + 19.6$ ($r = -0.721^{*}$). Tenebrionid beetles which are much larger in size than cucujid ones apparently require more heat for development. Despite such an allometric effect on the thermal requirement, each taxonomic insect group may have its own characteristic slope of regression line (Fig. 2). In fact, the slope of the regression line for Coleoptera was significantly steeper than that for Lepidoptera ($p < 0.05$).

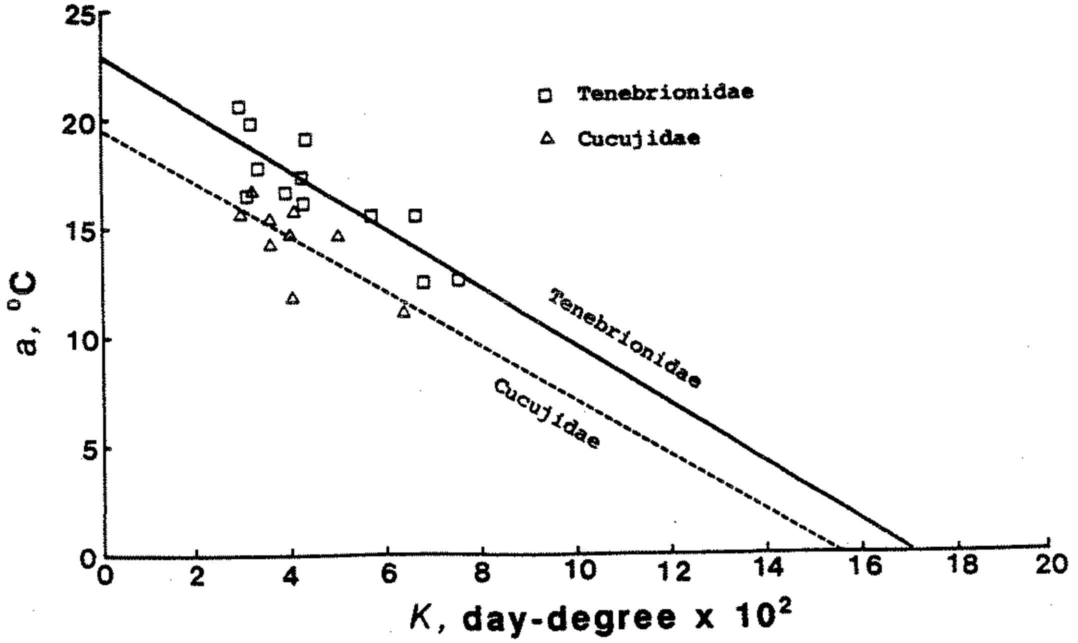

Fig. 2. Linear relationship between a and K in two coleopterous families, Tenebrionidae and Cucujidae.

The data analyzed in this study was based on those measured at constant temperatures. Fluctuating temperature may affect *K* and *a* of an insect but such effect is not so remarkable for a stored-product insect (Siddiqui and Barlow, 1973). Estimates of *a* and *K* from each developmental stage do not always coincide with those estimated from the total developmental period in an insect, but the difference between the sum of stage-specific *K*'s and a *K* estimated from the total developmental period is not significant in *Tribolium* species (Imura and Nakakita, 1984). Diapause is another important factor which affects distribution and abundance of insects. Diapause development of insects is, however, a much more complicated process than non-diapause development which was studied in this paper (Hodec, 1983). Therefore construction of an unified model which incorporates these two developmental processes has to wait future studies.

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Table 1. Thermal constant and threshold temperature for the development of stored-product insects

Species	Data analyzed		r.h.	Medium	r^f	Thermal constant day-degree		Threshold temper.°C		Data source/ Remarks
	no.	Range °C	%	/Host		$\bar{x}$	s.e.	$\bar{x}$	s.e.	
LEPIDOPTERA										
Pyralidae										
Ephestia cautella Walker	6	17.5 -30.0	70.0	9	0.994	532.4	29.5	12.6	0.7	Burges & Haskins(1965)
E. kuhniella Zeller	4	15.0 -25.0	70.0	3	0.995	1392.3	95.1	7.5	0.9	Jacob & Cox (1977)
	5	15.0 -30.0	67.0	7	0.995	760.2	42.4	8.2	0.8	Imura(1986)
	3	18.3 -30.0	$3.^{a}$	13	0.998	1320.1	77.4	7.1	1.0	Ahmad(1936)/slow st.
	3	18.0 -30.0	$3.^{a}$	13	0.996	762.8	68.1	9.1	1.4	do.(1936)/fast st.
E. elutella (Hubner)	4	15.0 -30.0	70.0	6	0.998	660.6	27.9	10.8	0.6	Bell (1975)
E. figlilella Gregson	6	17.5- 30.0	70.0	10	0.970	691.1	86.2	12.4	1.5	Cox (1974)
E. calidella (Guenee)	5	17.5 -30.0	70.0	11	0.983	386.3	42.3	15.3	1.1	do. (1974)
Plodia interpunctella (Hubner)	4	15.0 -30.0		12	0.994	599.5	38.3	10.8	0.8	Tamura (1978)
	3	20.0 -30.0	70.0	6	0.995	458.8	44.9	12.1	1.3	Bell (1975)
Ectomyelois ceratoniae (Zeller)	3	20.0 -30.0	70.0	12	0.998	441.6	26.5	10.6	0.9	Cox (1976)
Corcyra cephalonica (Steinton)	8	17.5 -30.0	70.0	20	0.978	422.1	45.0	14.9	1.1	Cox (1981)
Oecophoridae										
Hofmannophila pseudospretella (Steinton)	3	13.0 -20.0	90.0	12	0.996	1551.5	129.7	6.9	0.8	Woodroffe(1951a)
Endrosis sarcitrella (L.)	3	13.0 -20.0	90.0	12	0.999	869.6	23.6	8.5	0.2	Woodroffe(1951b)
COLEOPTERA										
Tenebrionidae										
Tribolium castaneum (Hubner)	5	22.5 -32.5	30.0	6	0.998	415.2	14.8	17.9	0.4	Howe (1956b)
	7	20.0 -35.0	70.0	6	0.998	334.0	10.5	17.8	0.3	do.
T. confusum Duval	5	20.0 -30.0	30.0	6	0.998	487.5	19.8	16.4	0.4	Howe (1960)
	6	20.0 -32.5	70.0	6	0.999	391.1	5.0	16.7	0.1	do.
T. madens (Charp.)	6	22.5 -35.0	70.0	6	0.986	425.7	36.0	17.4	1.0	Howe (1962)
T. anaphe Hinton	3	23.0 -27.0				312.0		16.5		Halstead(1967)/d,e
T. destructor Uyttenboogaart	7	16.0 -31.0	ca.75	15	0.984	755.4	61.5	12.6	1.1	Mathlein(1943)/c
T. freemani Hinton	6	20.0 -32.5	70.0	7	0.976	434.2	48.1	19.1	0.9	Imura & Nakakita(1984)
Palorus subdepressus (Wollaston)	4	20.0 -27.5	70.0	2	0.989	572.6	56.2	15.6	0.9	Halstead (1967)/e
P. laesicollis (Fairmaire)	3	17.5 -22.5	70.0	2	0.999	680.5	16.4	12.5	0.2	do.

Table 1. continued

P. ratzeburgi (Wissmann)	4	22.5 -32.5	70.0	2	0.996	427.3	26.7	16.1	0.7	do.
Coelopalorus foveicollis (Blair)	6	20.0 -32.5	70.0	2	0.995	663.6	33.8	15.5	0.6	do.
Latheticus oryzae Waterhouse	5	25.0 -35.0	35.0	7	0.990	326.5	27.5	20.5	0.9	N.-Slepowron /Slough N st.
	5	25.0 -35.0	35.0	7	0.987	286.6	26.8	21.5	0.9	& Aryeetey(1980)/Ghana st.
	6	25.0 -37.5	75.0	7	0.987	319.4	26.4	19.8	1.0	do./Slough N st.
	6	25.0 -37.5	75.0	7	0.987	295.3	24.6	20.6	1.0	do./Ghana st.
	6	25.0 -37.5	95.0	7	0.987	308.2	25.6	20.4	1.0	do./Slough N st.
	6	25.0 -37.5	95.0	7	0.987	296.1	24.4	20.7	0.9	do./Ghana st.
Anobiidae										
Lasioderma serricorne (F.)	4	22.5 -30.0	50.0	6	0.998	453.4	21.9	16.3	0.5	Howe (1957)
	5	20.0 -30.0	70.0	6	0.995	411.8	23.8	16.2	0.6	do.
Stegobium paniceum (L.)	5	17.5 -27.5	70.0	6	0.998	556.6	18.9	14.5	0.3	Lefkovitch (1967)/male
	5	17.5 -27.5	70.0	6	0.997	626.3	26.1	13.2	0.4	do./female
Cucujidae										
Oryzaephilus surinamensis (L.)	3	20.0 -30.0	5.[a]	13	0.999	295.0	15.7	15.6	0.5	Thomas & Shepard(1940)
	3	20.0 -30.0	5.[a]	21	0.993	366.2	42.7	14.5	1.3	do.
O. mercator (Fauvel)	4	20.0 -27.5	70.0	6		318.9		16.6		Howe(1956a)/d
O. acuminatus Halstead	6	20.0 -32.5	70.0	14	0.987	357.0	29.5	15.4	1.0	Jacob (1981)
Cryptolestes ferrugineus (Stephens)	7	20.0 -35.0	70.0	4	0.994	407.0	20.2	15.7	0.6	Smith (1965)
C. turcicus (Grouvelle)	4	17.5 -25.0	90.0	6	0.993	398.4	32.5	14.7	0.6	Lefkovitch (1962a)/c
C. pusillus (Schonherr)	6	20.0 -32.5	70.0	6	0.999	499.3	5.0	14.6	0.1	Currie (1967)
	6	20.0 -32.5	90.0	6	0.992	339.9	21.1	14.7	0.8	do.
C. pusilloides (Steel & Howe)	6	17.5 -30.0	90.0	6	0.982	402.4	38.3	11.8	1.2	Lefkovitch (1964)
C. capensis (Waltl)	8	15.0 -32.5	90.0	6	0.994	638.3	28.3	11.1	0.6	Lefkovitch (1962b)
C. ugandae Steel & Howe	6	17.5 -30.0	90.0	6	0.991	356.3	24.3	14.2	0.7	Lefkovitch (1957)
Mycetophagidae										
Typhaea stercorea (L.)	5	20.0 -30.0	80.0	1	0.996	393.8	19.6	14.5	0.6	Jacob (1988)
Curculionidae										
Sitophilus oryzae (L.)	5	15.2 -29.1	14.[b]	1	0.996	422.1	23.3	13.6	0.6	Birch (1953)
	3	20.0 -30.0	76.0	17	0.998	466.7	29.9	13.5	0.8	Ohara & Yasue (1975)
S. zeamais Motschulsky	3	20.0 -30.0	76.0	17	0.999	440.0	12.1	14.4	0.3	do.
S. granarius (L.)	6	15.0 -30.0	70.0	1	0.982	517.6	50.4	10.5	1.3	Estham & Segrove(1947)
Bostrichidae										
Rhyzopertha dominica (F.)	6	22.0 -32.0	70.0	1	0.992	388.5	24.5	17.5	0.6	Howe (1950)
Prostephanus truncatus (Horn)	6	18.0 -30.0	70.0	19	0.994	403.2	21.6	15.1	0.5	Bell & Watters(1982)
	4	20.0 -27.0	90.0	19	0.983	416.2	55.5	16.2	1.0	do.

Table 1. continued

Dermestidae											
Dermestes frischii Kug.	6	20.0	-33.0	70.0	27	0.998	541.5	16.4	15.2	0.4	Howe (1953)
Trogoderma granarium Everts	3	25.0	-35.0	25.0	16	0.986	656.3	109.7	13.3	2.8	Hadaway(1956)/male
	3	25.0	-35.0	25.0	16	0.999	687.1	2.0	14.2	0.1	do./female
	3	25.0	-35.0	73.0	16	0.999	524.7	17.1	13.9	0.6	do./male
	3	25.0	35.0	73.0	16	0.998	613.6	39.1	13.3	1.0	do./female
T. versicolor (Creutz.)	3	20.0	-30.0	25.0	16	0.957	653.8	197.1	16.9	2.7	do./male
	3	20.0	-30.0	25.0	16	0.956	726.7	222.6	16.7	2.9	do./female
	3	20.0	-30.0	73.0	16	0.981	510.4	102.2	17.1	1.8	do./male
	3	20.0	-30.0	73.0	16	0.976	601.9	133.5	17.1	2.0	do./female
Ptinidae											
Ptinus ocellus Brown	6	10.0	-23.0	70.0	5	0.992	818.9	52.4	7.5	0.7	Ewer & Ewer(1942)
	4	13.0	-25.0	70.0	6	0.996	860.2	57.4	7.1	0.9	Howe & Burges(1953a)
P. pusillus Sturm	4	17.5	-25.0	70.0	3	0.928	685.5	193.9	16.5	1.6	Howe (1956c)
Mezium affine Boieldieu	3	20.0	-30.0	70.0	6	0.991	1140.5	153.7	11.2	1.9	Howe & Burges(1953b)
Gibbium psylloides (Czenp.)	4	20.0	-33.0	70.0	6	0.999	942.0	26.5	11.8	0.5	Howe & Burges(1952)
Nitidulidae											
Carpophilus hemipterus L.	4	15.0	-30.0	75.0	26	0.998	566.4	28.3	8.6	0.8	Cangardel(1981)
C. ligneus Murray	4	15.0	-30.0	75.0	26	0.995	640.5	44.7	8.5	1.1	do.
Bruchidae											
Callosobruchus chinensis (L.)	7	20.0	-31.0	ca.32	22	0.992	656.3	37.8	9.4	0.9	Ishikura(1941)/male
	7	20.0	-31.0	ca.32	22	0.991	671.7	41.6	9.3	1.0	do./female
	6	20.0	-31.0	ca.55	22	0.988	547.7	43.0	10.1	1.3	do./male
	6	20.0	-31.0	ca.55	22	0.986	553.1	46.7	10.0	1.4	do./female
	7	20.0	-31.0	ca.75	22	0.998	478.1	46.2	10.1	1.5	do./male
	7	20.0	-31.0	ca.75	22	0.980	463.6	42.5	10.6	1.4	do./female
	7	20.0	-31.0	ca.93	22	0.997	420.2	14.8	11.3	0.5	do./male
	7	20.0	-31.0	ca.93	22	0.998	425.4	12.6	11.3	0.4	do./female
C. maclatus (F.)	3	22.5	-30.0	70.0	22	0.999	358.0	3.0	14.9	0.1	Howe & Currie(1964)
C. analis (F.)	4	22.5	-30.0	70.0	23		407.4		16.6		do./c,d
C. rhodesianus (Psi.)	4	17.5	-30.0	70.0	22	0.999	423.0	15.3	13.7	0.4	do.
Zabrotes subfasciatus (Boh.)	5	20.0	-30.0	70.0	24		415.4		15.0		do./d
Acanthoscelides obtectus (Say)	5	17.6	-30.1	90.0	25	0.997	510.2	21.2	11.7	0.5	Menusan(1933)/male
	5	17.6	30.1	90.0	25	0.998	524.6	19.0	11.7	0.5	do./female

Table 1. continued

HEMIPTERA										
Anthocoridae										
Xylocoris flavipes (Reuter)	3	20.0 -30.0	75.0	28	0.999	231.1	4.9	15.5	0.2	Arbogast(1975)
HYMENOPTERA										
Ichneumonidae										
Ventria canescens (Gravenhorst)	4	15.0 -27.0	ca.70	29	0.999	358.8	12.6	11.4	0.4	Ahmad(1936)/female
Pteromalidae										
Aplastomorpha calandrae (Howard)										
	5	24.0 -32.0	ca.75	30	0.969	177.0	25.9	16.3	1.8	Utida & /male
	5	24.0 32.0	ca.75	30	0.986	187.6	17.3	16.4	1.1	Nagasawa(1949)/female
Braconidae										
Bracon hebetor Say	7	20.0 -36.0		29	0.992	185.8	10.53	10.6	1.1	Payne(1933)
	4	20.0 -35.0	ca.50	31	0.997	164.6	9.1	10.5	1.0	Jackson & Butler(1984)
B. brevicornis Wesmael	5	22.5 32.5	ca.50	31	0.994	104.7	6.5	16.0	0.7	do.

[a] Saturation deficit; [b] Moisture content; [c] based on the first adult emergence; [d] the data were read from a figure; [e] fitting the linear equation was not satisfactory for the data; [f] Correlation coefficient.

Medium/Host: 1. wheat; 2. whole-wheat flour; 3. wheat flour; 4. wheat flour + wheat germ; 5. wheat flour + casein + yeast;6. wheatfeed; 7. wheatfeed + yeast; 8. wheatfeed + yeast + glycerol; 9. wheatfeed + wheat germ + yeast; 10. wheatfeed + glucose + yeast; 11. wheatfeed + glucose + yeast + glycerol; 12. middling; 13. oats; 14. oatmeal; 15. rye flour; 16. malt; 17. brown rice; 18. rice bran; 19. maize; 20. soybean meal + sucrose; 21. walnuts; 22. cowpea; 23. garden pea; 24. haricot bean; 26. prune; 27. fishmeal + yeast; 28. P. interpunctella larva; 29. E. kuhniella larva; 30. C. chinensis larva; 31. P. gossypiella larva.

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THE EFFECT OF VARIOUS CONCENTRATIONS OF TRICALCIUM PHOSPHATE ON FECUNDITY AND HATCHABILITY IN TWO SPECIES OF TRIBOLIUM

INTRODUCTION

Food for stored product pests is a very important ecological factor that limits, among other factors, the population numbers. Insects need not only the presence of particular components in the diet for normal growth and development, but also suitable proportions of these components. An unsuitable ratio of the components in insect food or the absence of one or more components causes a disturbance in insect populations such as delay of development, a change in fecundity and hatchability. Pratt et al. (1972) reported that the use of mineral salts offers a new promissing method for insect control. These authors suggested to increase the level of different elements (e.g. Fe, Cu, F, and Mg) to required high concentrations controlling pests. It was found that the strongest inhibitory effect for stored product pests was that of ammonium nitrate and tricalcium phosphate (Boczek 1984). For example, the tricalcium phosphate (TCP) has proven to be a good source of calcium and phosphate for man and domestic animals and at the same time a 1 - 3% concentration of this compound is enough to protect the stored flour and grain from the insect infestation.

The paper aimed at learning about response of 6- and 7-instar groups of strain of Tribolium castaneum cI (discerned earlier by Prus 1976) and T. confusum Duval bIV (discerned earlier by Bijok 1984) to different concentrations of TCP in the food. Both fecundity and hatchability were examined.

MATERIAL AND METHODS

Experiments were carried out on cI strain of T. castaneum and bIV strain of T. confusum. In this strain, 6- and 7-instar groups were discerned and cultured at 29° C and relative humidity 75% in dark incubator. Standard mixture of wheat flour and baker's yeast in weight proportion 20:1 was used as culture medium. To culture medium tricalcium phosphate was added in adequate proportions to obtain three concentrations: 0.5, 1.0 and 1.5% (by weight). The substance originated from USDA Laboratory, Savanah, Georgia. The standard culture medium was use as a control sample.

For experiments on fecundity the animals that were cultured previously for developmental time and survival studies (Prus 1989) were mated and kept in vials as a single pairs in 8 g of either pure culture medium or with different concentration of TCP. For each concentration 10 replicates were set up. The experiments were carried out for 30 days and in every 3-day period the number of eggs laid by female was counted. The eggs collected from vials were transferred to small vials and left over in incubator for 6 days to develop. After this period the hatchability of eggs was estimated.

An additional series of experiments were performed where animals cultured initially in TCP concentrations of 0.5 and 1,0% in the medium were transferred to pure medium in which their fecundity and hatchability were tested. This allowed to evaluate the effect of temporary lack of harmful agent in the medium.

The data obtained for fecundity were statistically elaborated using three factor design of analysis of variance (Simpson et al. 1960). The computer programme specially outlined for these data by Dr P. Bijok of the Institute of Ecology was used.

RESULTS

The fecundity of T. castaneum is restricted under the effect of TCP. The concentration of 0.5% limits fecundity by about 15% as compared with control series in 6-instar group and by about 20% in 7-instar group (Fig. 1). The decrease by more than 50% in 6-instar and by 30% in 7-instar group at concentration 1.0% was observed. At concentration 1.5% of TCP in 6-instar individuals mortality was the highest. It resulted in reduction of replications from 10 to 2. In 7-instar group the latter concentration caused a decrease of fecundity by about 60%.
In series where animals were transferred to control medium from 0.5 and 1.0% concentration of TCP, the fecundity was similar to control one irrespective to the concentration at which the development of animals previously took place.

The data obtained for fecundity were statistically elaborated using analysis of variance. In T. castaneum (Table 1) all effects and their interaction are highly significant at probability level of 0.005. This means that fecundity of T. castaneum is a very susceptible trait affected significantly by all factors.

The hatchability of eggs in T. castaneum in all series of experiment is practically the same as in control (Fig. 2). The hatchability sometimes is higher in various series of TCP concentration than in control one.

In T. confusum this salt also decreases the rate of fecundity but to a lesser degree. In 6-instar group the concentration of 1.0% of TCP affects fecundity stronger than concentration 1.5% (Fig. 3). Similarly as in T. castaneum, the fecundity in this species after transferring the beetles from

TCP to control medium is practically the same as in the control series.

The results for fecundity in T. confusum were also elaborated using analysis of variance (Table 2). On the contrary to results obtained for T. castaneum, in T. confusum the effect of time is weak one (F = 10.07 as compared with F = 55.55 for T. castaneum) which has some bearing on results, bringing insignificant interaction: time x instar group and time x instar group x concentration.

The hatchability of eggs in T. confusum in all series of experiments similarly as in T. castaneum is practically the same as in the control series (Fig. 4). Hatchability being a very variable parameter, does not show any consistent differences within instar groups in both species, it is also independent of TCP concentration. Due to this fact no statistical analysis was performed with material on hatchability.

The time effect on fecundity and hatchability is different. Fecundity decreases with time gradually whereas hatchability maintains the same level from the beginning of experiment to its end.

DISCUSSION

It is known from previous paper (Prus et al. 1988) that in T. castaneum cI females of 6-instar group lay more eggs than females of 7-instar group. This phenomenon is also observed in the present paper, where in spite of various concentration of TCP in each series females from 6-instar group lay more eggs than those from 7-instar group. From the above mentioned paper it is also evident that maximum fecundity occurs during the first month of adult life, so in this experiment only this period was examined. The results, as presented in Fig. 1 show that TCP decreases fecundity and that this decrease is highest in concentration 1.5% in both groups of this species. It is very difficult to explain why concentration of 1.0% affects 6- and 7-instar groups of T. confusum (Fig. 3)stronger than that of concentration of 1.5%. A similar phenomenon was observed in Oryzaephilus surinamensis (L.) under the effect of potassium nitrate in different concentrations (Hassan 1981). In this case concentration of 1.0% of this salt was decreasing strongly the number of total progeny, while the concentration of 3% show the opposite effect.

In both species and both discerned instar groups the transfer of animals from medium with TCP to pure medium caused recovery of fecundity, practically to the same level as in control (Fig. 1 and 3). The same results were obtained by Ignatowicz (1980) for Sitophilus granarius (L.) fed with wheat grains impregnated by various concentrations of potassium iodine. The animals which were transferred to the pure wheat graines recovered their reproductive abilities rather quickly during their further life.

In this experiment hatchability in both species and in both discerned groups has shown no consistent differences caused by the effect of TCP (Fig. 2 and 4), whereas the significant decrease of this parameter was observed in O. surinamensis at a concentration 1.0 of TCP and in T. granarium at a concentration 2.0% of this salt was observed by Hassan (1981).

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EXPLANATIONS TO FIGURES

Fig. 1. The effect of various concentration of tricalcium phosphate on fecundity of Tribolium castaneum Hbst cI strain
1 - concentration 0.5%, 2 - 1.0%, 3 - 1.5%, 4 - control, 5 - 0.5% ---- C, 6 - 1.0% ---- C

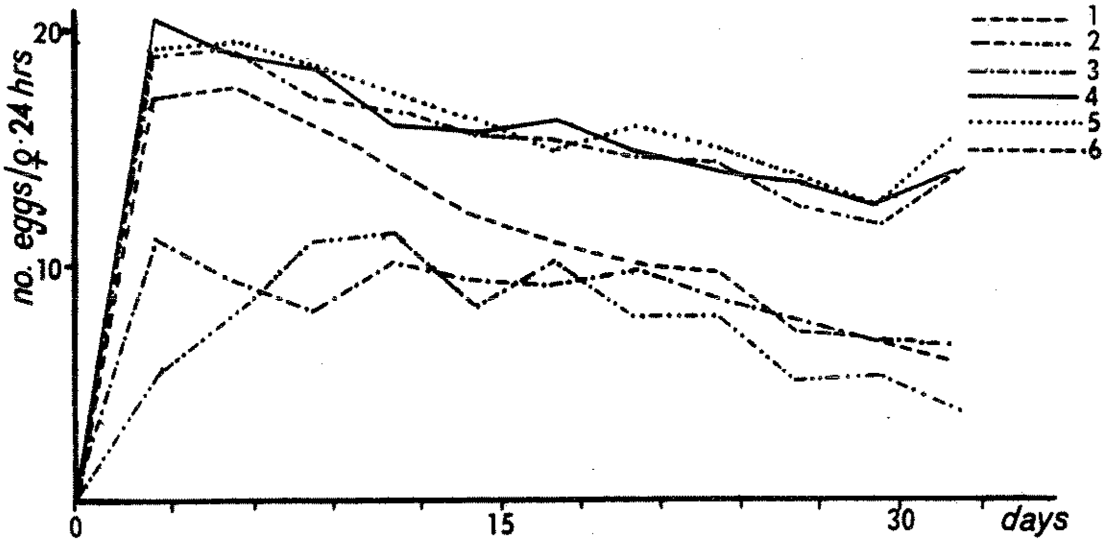
Fig. 2. The effect of various concentration of tricalcium phosphate on hatchability of Tribolium castaneum Hbst cI strain.
Explanations - as in Fig. 1

Fig. 3. The effect of various concentration of tricalcium phosphate on fecundity of Tribolium confusum Duval bIV strain.
Explanations - as in Fig. 1

Fig. 4. The effect of various concentration of tricalcium phosphate on hatchability of Tribolium confusum Duval bIV strain.
Explanations - as in Fig. 1

Fig.1

6- instar group



7- instar group

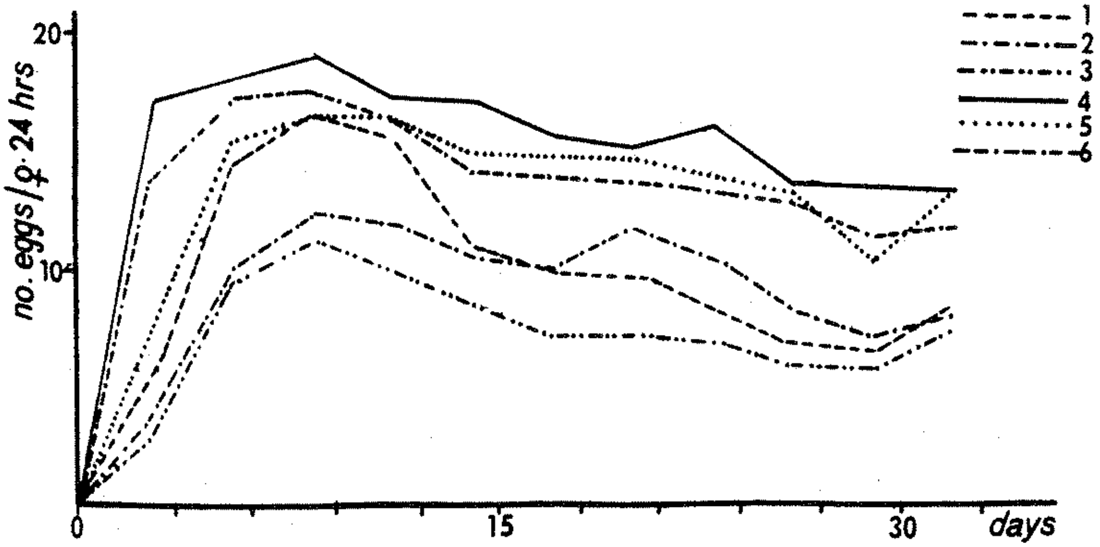


FIG. 2

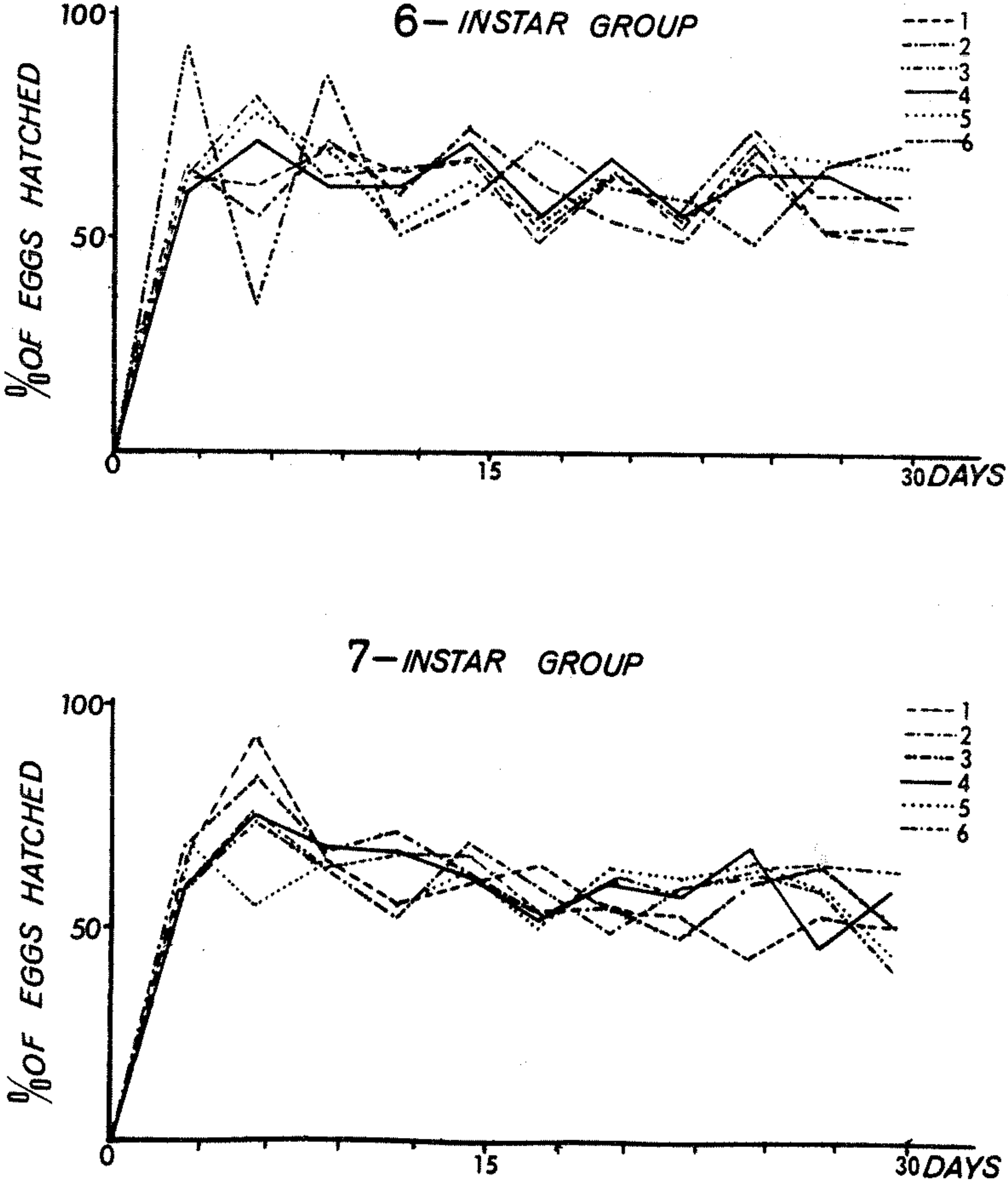

6-INSTAR GROUP
% OF EGGS HATCHED
100
50
0
15
30 DAYS
1
2
3
4
5
6
7-INSTAR GROUP
% OF EGGS HATCHED
100
50
0
15
30 DAYS
1
2
3
4
5
6

Fig. 3

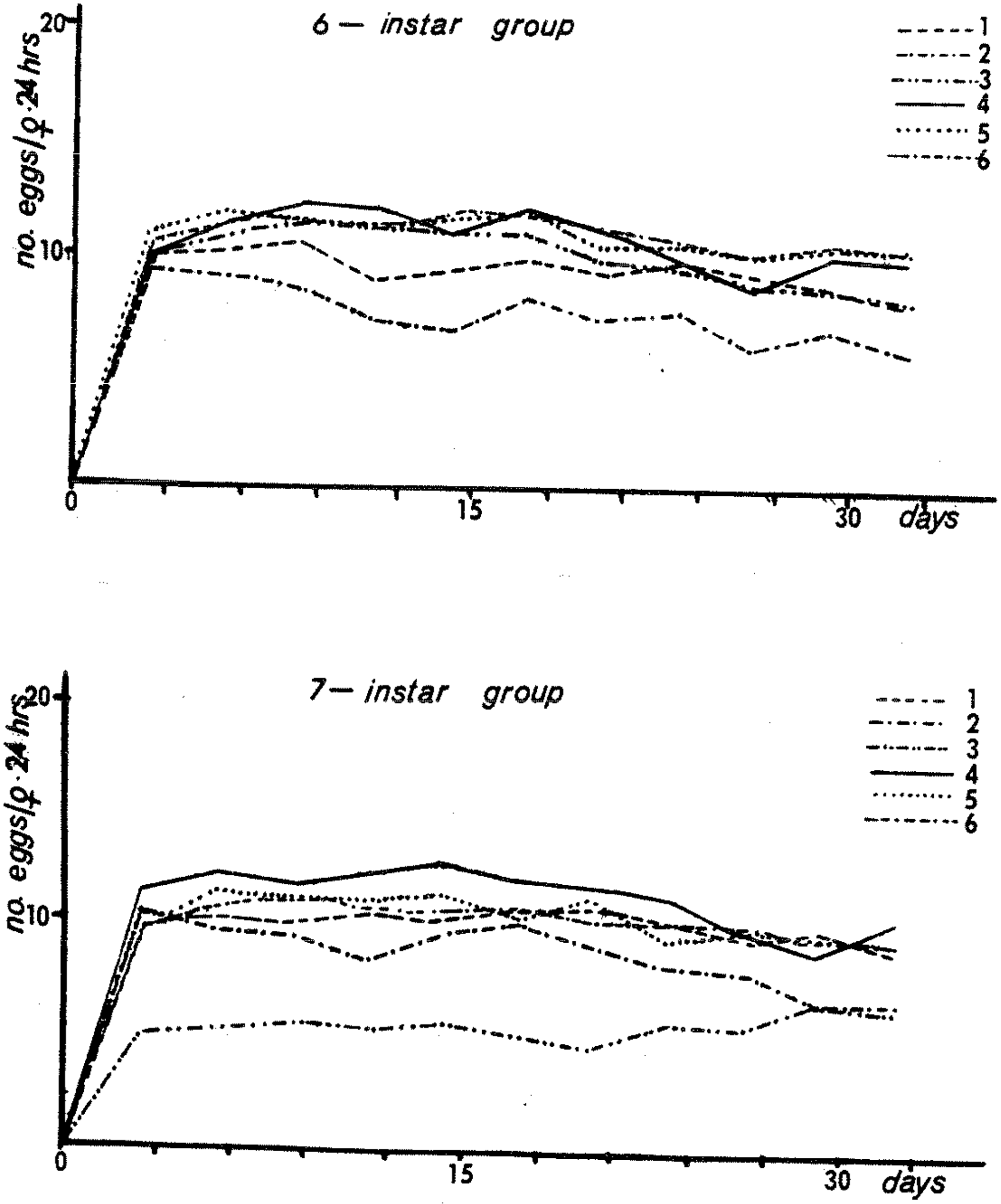

6 — instar group
no. eggs/♀·24 hrs
20
10
0
15
30
days
1
2
3
4
5
6
7— instar group
no. eggs/♀·24 hrs
20
10
0
15
30
days
1
2
3
4
5
6

FIG.4

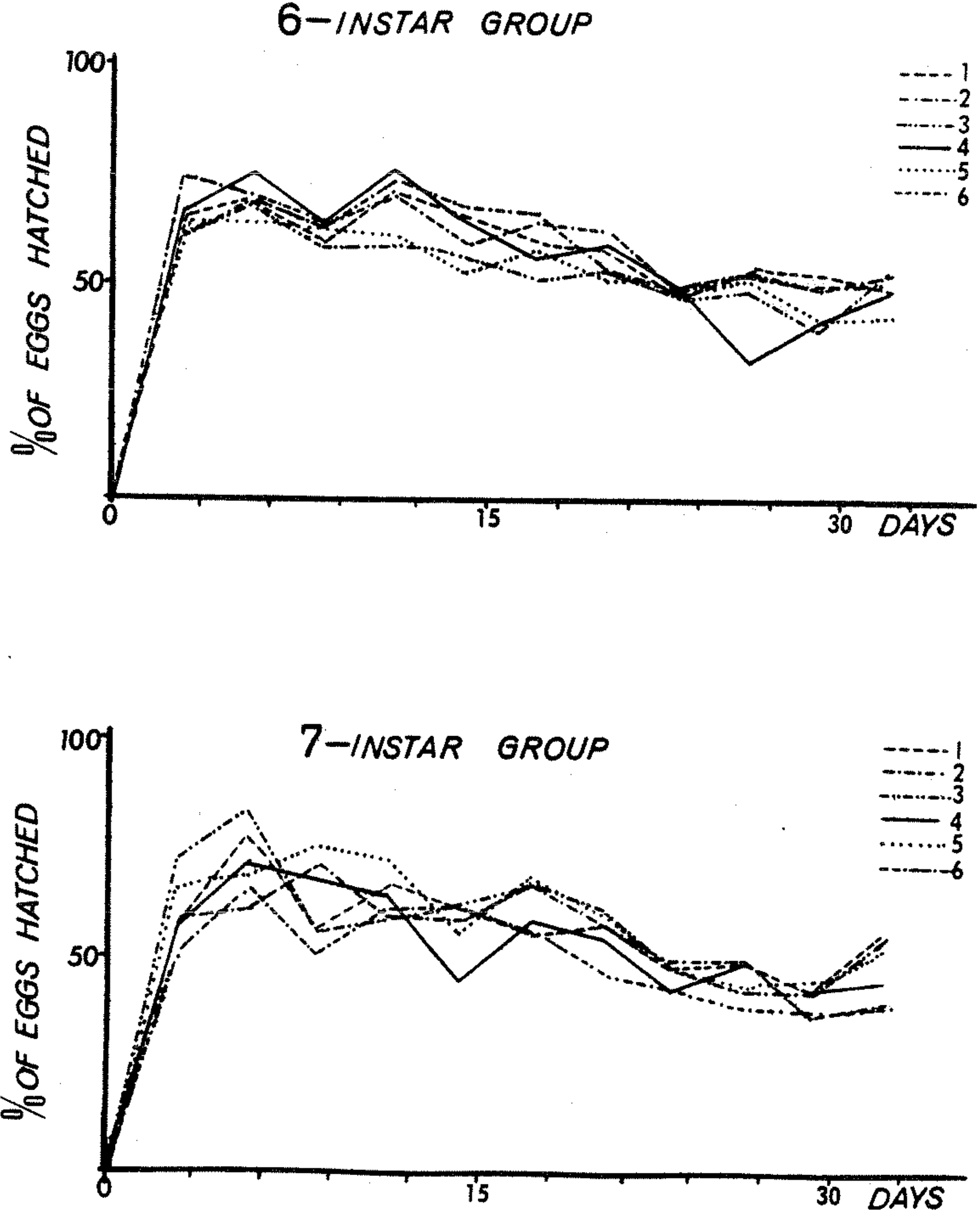

6–INSTAR GROUP
100
50
0
15
30
DAYS
% OF EGGS HATCHED
1
2
3
4
5
6
7–INSTAR GROUP
100
50
0
15
30
DAYS
% OF EGGS HATCHED
1
2
3
4
5
6

Table 1. Analysis of variance of fecundity in _Triboli_ _castaneum_ Hbst.

Source of of variation	Sum of squares	d.f.	Mean square	F	P
time	4219.3	10	421.9	55.55	0.00
concentration	7715.2	4	1928.8	263.95	0.00
instar group	189.3	1	189.3	24.93	0.00
interaction:					
time x concentration	1233.3	40	30.8	4.06	0.0
concentration x instar group	337.3	4	84.3	11.10	0.0
time x instar group	1374.2	10	137.4	18.09	0.0
time x instar group x concentration	400.2	40	10.0	1.32	0.0
deviations	7519.2	990	7.6		
total	22988.0	1099			

Table 2. Analysis of variance of fecundity in Triboli confusum Duval

Source of variation	Sum of squares	d.f	Mean square	F	P
time	479.1	10	47.9	10.07	0.00
concentration	2170.0	5	434.0	91.24	0.00
instar group	156.7	1	156.7	32.58	0.00
interaction:					
time x concentration	213.7	50	4.3	0.90	NS
concentration x instar group	1195.4	5	239.1	50.27	0.0
time x instar group	32.3	10	3.2	0.68	NS
time x instar group x concentration	202.1	50	4.0	0.85	NS
deviations	5650.6	1188	4.7		
total	10099.9	1319			

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INTRAPOPULATION DIFFERENTIATION OF TRIBOLIUM CASTANEUM HBST. cIV AND T. CONFUSUM DUVAL bI

INTRODUCTION

Searching for intrapopulation differentiation within populations of flour beetles as a possible mean of response to environmental factors leading to better survival under certain conditions the other genetic strains: *T. castaneum* cIV and *T. confusum* bI were tested. In our previous papers we have tested in this respect *T. castaneum* cI (Prus 1976, Prus and Prus 1987), *T. confusum* bIV (Bijok 1984, Prus et al. 1988) and two black mutants: *T. castaneum* "sooty" and *T. confusum* "ebony-2" (Prus - in print).

The strain cIV of *T. castaneum* is characterized by the lowest productivity whereas the strain bI of *T. confusum* - by the highest one (Park et al. 1961, 1965).

The aim of the present paper was to check two strains of flour beetles whether they also show differentiation similar to that observed in previously tested strains.

The whole experimental work for this paper has been done in the Whitman Laboratory, Department of Biology, University of Chicago during our one-month visit in 1989.

MATERIAL AND METHODS

The material used for this work were strains of Tribolium from Whitman Laboratory, University of Chicago. The method used to test the strains for heterogeneity was similar to that applied earlier by Prus (1976) and Bijok (1984). It depended on individual culturing of single specimens from egg to the adult stage, each at 1 g of culture medium consisting of weat flour and dry powdered yeast at proportion 20:1 by weight. The cultures were run in a dark incubator at a temperature of 29 C and relative humidity of 75%.

The census was done every day consisting of looking for the skin cast in the culture vials. Every second day the animals were weighed starting from the 11th (*T. confusum*) or 12th (*T. castaneum*) day of development of larvae. A total of 120 replicates was set up, 60 for each of the two strains. The results obtained were later drawn as individual growth curves of wet weight grouped according to sex (determined at the pupal stage) within each strain. Depending on the number of exuviae, the individuals were classified either as 6- or 7-instar group.

Later on the growth curves were averaged for each instar groups separately, resulting in mean growth curves for 6- and 7-instar group. The incidence of each group within ca 60 individuals of each species was also determined.

Another experiment performed simultaneously aimed at determining the frequency of appearance of pupae in group cultures of these strains. To achieve this, synchronized cultures were set up with eggs 0 to 24 hours old. From the moment of appearnace of pupae they were removed, counted, weighed (in order to assess individual pupal weight) and their sex determined. Then, frequencies of both sexes in the two strains were drawn against time which allowed to judge whether there was one or two peaks of pupal appearance in a given strain. This would imply the presence or not of different phenotypic groups within each strain, corroborating thus the results based on individual cultures. Differences in mean weight of pupae with time of their appearance were analyzed as to the existence of the two groups in populations.

Attention should be drawn to the fact that time in days in individual cultures (Fig. 1 and Table 1) was counted from the moment of larvae hatching from eggs, whereas in the group eperiments (Figs 2 and 3) - from the moment when eggs have been laid by females. Thus developmental time in the first case does not include the duration of egg stage (4 or 5 days depending on the species) and in the second one it does include it.

RESULTS AND DISCUSSION

The two strains tested differ in the respect of their intrapopulation differentiation, cIV of T. castaneum being heterogenic and bI of T. confusum - a homogenic strain. Within former two groups of 6- and 7-instar groups were distinguished whereas the latter consisted only of 7-instar individuals (Fig. 1 A). The proportion of 6- to 7-instar group in T. castaneum was around 1 to 6 similar for both sexes (Table 1). The 6-instar individuals were much lighter than the remaining group and they pupated one and a half day earlier than the 7-instar individuals. More or less similar trends in changes of coefficient of variation within distinguished groups of T. castaneum cIV strain and that for uniform strain T. confusum bI. Concerning the body weight during development corroborate the rightness of distinguishing these groups in cIV strain and no groups in bI strain.

Group experiments with T. castaneum cIV strain revealed that the earlier appearing pupae (on 18 to 20th day of development following the hatching from eggs) showed much lower individual dry weight than that of pupae appearing later both in females and males. These two groups of pupae correspond closely to the two peaks of appearance of pupae in time - synchronized cultures of this strain (Fig.2). By and large, different courses of growth curves, differences in pupal weight and two peak curve of pupal of pupal appearance: all this proves the heterogeneity of cIV strain.

In bI strain of T. confusum only one group of 7-instar individuals was observed. Its growth curves for females and males are presented in Fig. 1B. The mean time of appearance of pupae in individual cultures was 21.2 day of development after the moment of egg hatching for females and 21.5 day for males. It is interesting to note that coefficient of variation is diminishing as the larvae grow reaching the lowest value at the prepupal and pupal stage (Table 1).

The group experiments with bI strain of T. confusum showed rather one peak of appearance of pupae in synchronized cultures with females showing a slight tendency to split into two peaks of appearance (Fig. 3). The individual weight of these pupae against time of their appearance, however, prove that the strain is phenotypically homogenous as evidenced by rather straight lines on the upper graph of Fig. 3. Lighter pupae found on the first day of appearance did not contradict the general conclusion of uniform pupal weight in this strain, but can result from different reasons.

Having investigated the two other strains of Chicago genetic strains in respect of phenotypic heterogeneity the following can be concluded.

T. castaneum reveals higher tendency to phenotypic heterogeneity within a group of four strains than does T. confusum. Both investigated strains cI (Prus 1976, Prus and Prus 1987, Prus et al. 1988) and cIV consist of 6- and 7-instar group, however thair incidences differ. In cI this proportion seems to be 1:1 and in cIV 7-instar group is clearly prepondering over the 6-instar group.

In T. confusum such heterogeneity was also observed but only in bIV strain (Bijok 1984, Prus et al. 1988) whereas bI strain is homogenous in this respect. Proportion between the discerned groups in bIV is variable, perhaps on account of methodological error (starting an experiment with newly hatched larvae instead of randomly chosen eggs).

Similar trends were observed in black mutants of these species, semidominant "sooty" strain of T. castaneum was much more differentiated than "ebony-2" of T. confusum, which was almost homogenous (Prus in print).

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EXPLANATIONS TO FIGURE

Fig. 1. Mean growth curves of *Tribolium castaneum* cIV (A) and of *T. confusum* bI (B) for females and males. Vertical lines denote moment of appearance of pupae

Fig. 2. Mean weight (A) and frequency of appearance of pupae (B) in synchronized cultures of *T. castaneum* cIV strain.

Fig. 3. Mean weight (A) and frequency of appearance of pupae (B) in synchronized cultures of *T. confusum* bI strain.

Fig.1

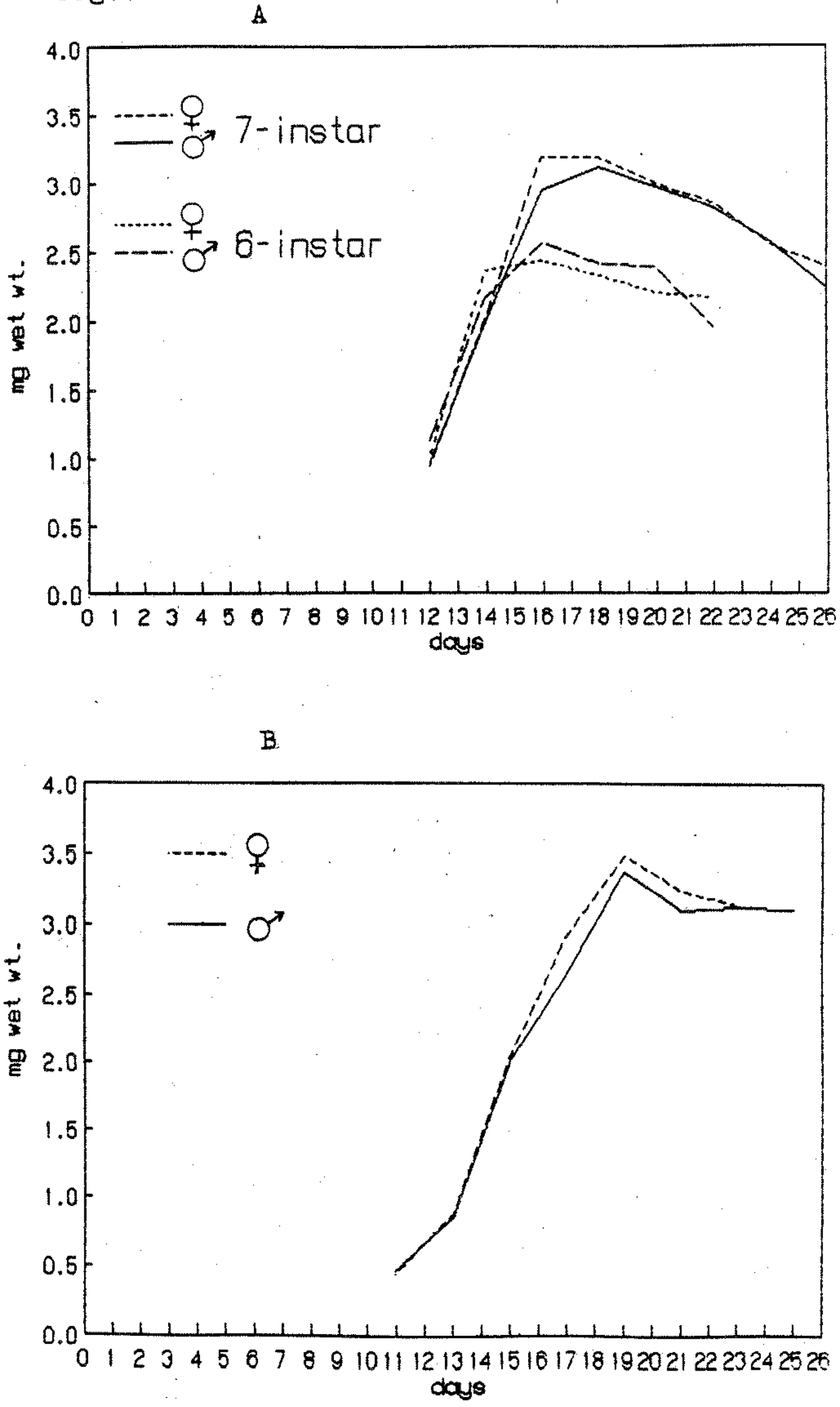
A
♀ 7-instar
♂ 7-instar
♀ 6-instar
♂ 6-instar
mg wet wt.
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
days
B
♀
♂
mg wet wt.
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
days

Fig. 2

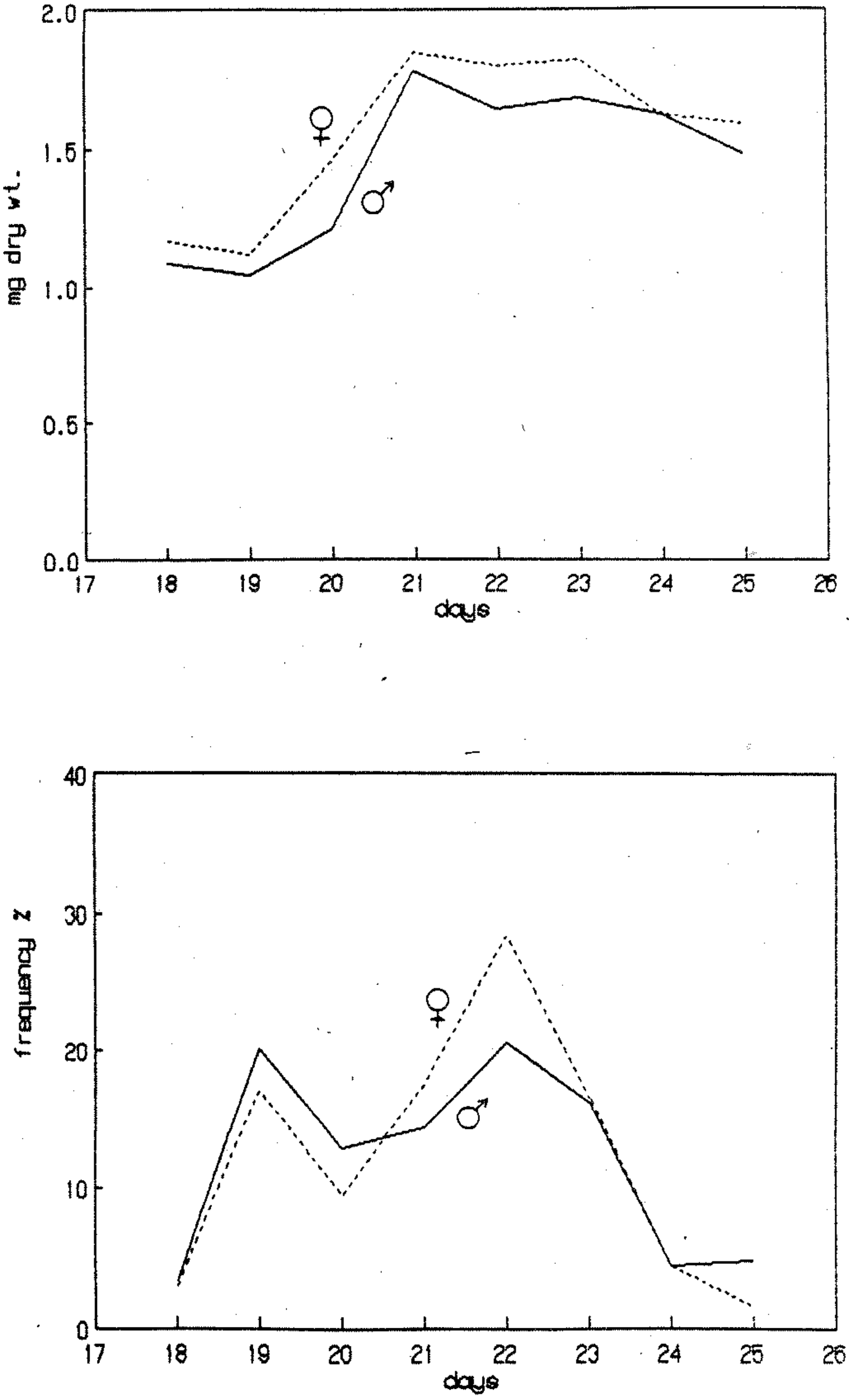
2.0
1.5
1.0
0.5
0.0
mg dry wt.
♀
♂
17
18
19
20
21
22
23
24
25
26
days
40
30
20
10
0
frequency %
♀
♂
17
18
19
20
21
22
23
24
25
26
days

Fig.3

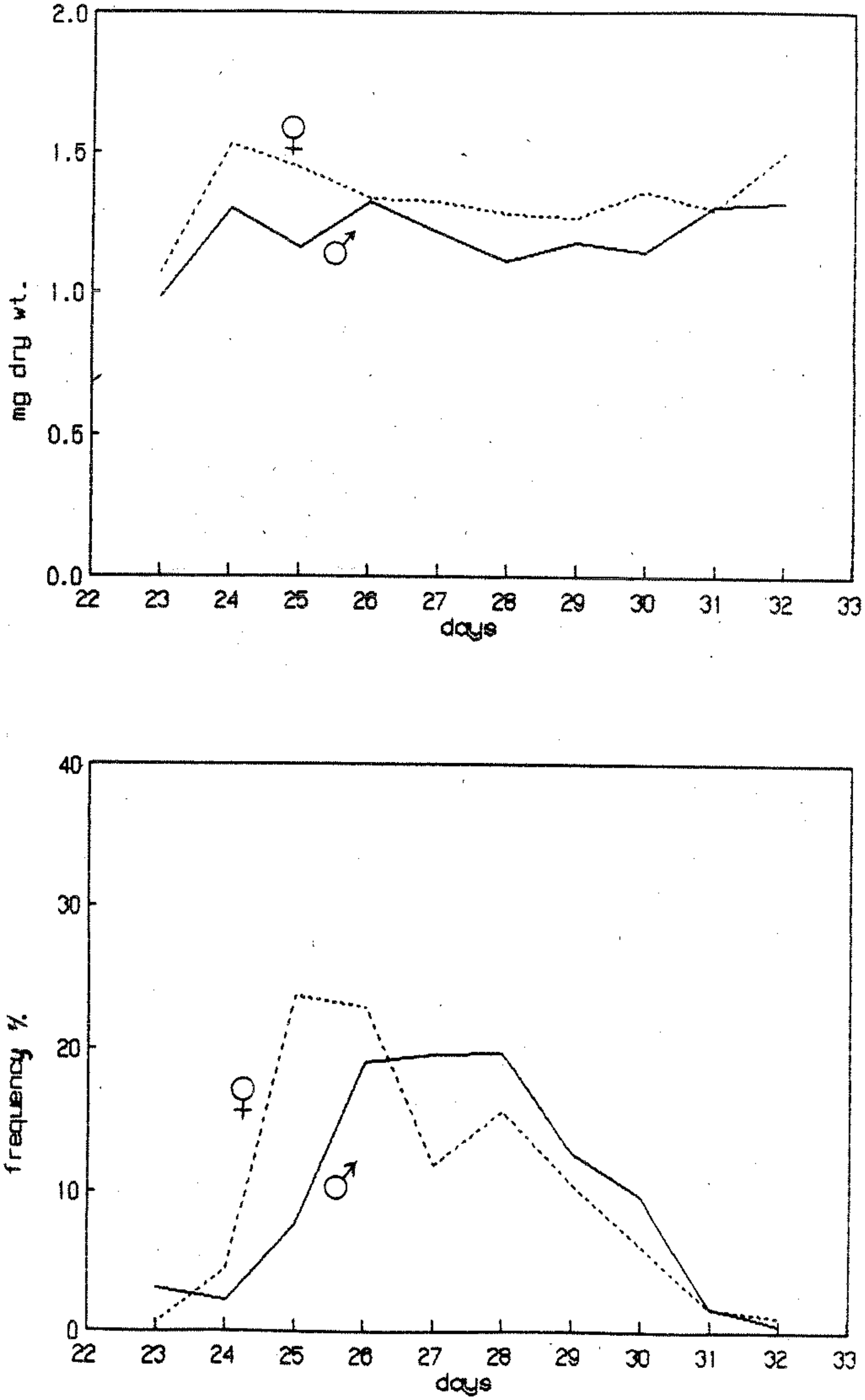
2.0
1.5
1.0
0.5
0.0
mg dry wt.
♀
♂
22
23
24
25
26
27
28
29
30
31
32
33
days
40
30
20
10
0
frequency %
♀
♂
22
23
24
25
26
27
28
29
30
31
32
33
days

Table 1. Body weight changes during development of an individual.

Tribolium castaneum cIV

Sex & instar group		Days of development							
		12	14	16	18	20	22	24	26
♀♀ 6-instar	x	1.01	2.36	2.43	2.29	2.21	2.18		
n = 3	cv(%)	14.4	17.2	3.5	1.4	1.8	1.9		
♂♂ 6-instar	x	1.14	2.17	2.56	2.41	2.40	1.96		
n = 2	cv(%)	5.0	2.0	0.6	0.6	5.9	1.1		
♀♀ 7-instar	x	0.94	2.03	3.19	3.16	3.01	2.86	2.56	2.40
n = 17	cv(%)	19.6	16.5	14.3	8.6	5.7	7.3	9.5	9.5
♂♂ 7-instar	x	0.98	2.00	2.94	3.12	2.99	2.83	2.59	2.38
n = 18	cv(%)	28.0	13.3	15.8	6.4	7.4	7.9	14.5	12.5

Tribolium confusum bI

Sex & instar group		Days of development						
		11	13	15	17	19	21	23
♀♀ 7-instar	x	0.44	0.89	2.06	2.93	3.49	3.23	3.14
n = 25	cv(%)	29.5	15.2	14.2	18.0	3.5	5.6	5.3
♂♂ 7-instar	x	0.47	0.86	2.02	2.65	3.37	3.10	3.13
n = 26	cv(%)	26.8	21.2	17.7	21.2	6.2	5.9	8.5

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