TRIBOLIUM INFORMATION BULLETIN

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TRIBOLIUM INFORMATION BULLETIN

Number 33

July, 1993

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

STEVENS/GOODNIGHT LAB

Tribolium confusum

bI
bII
bIII
bIV
b-Chicago b/b
b-Chicago
b-Circle
b-yugo-Illinois b/b
b-yugo-Illinois +/+
bSM
b-yugo-Kentucky
b-McGill
b-Thailand
b-Nigeria
b-Pakistan

Tribolium castaneum

cI
cSM-+/+
cSM-b/b
cIV-a
c-Brazil
c-Costa Rica
c-Thailand
c-Spain
c-Israel

Oryzaephyllus surnamensis

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

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. castaneum - Chicago black-- Sokoloff
T. castaneum - sooty (Sokoloff)
T. castaneum - dark sooty (Sokoloff)
T. castaneum - Charcoal--Sokoloff
T. castaneum - tawny/pearl--Sokoloff

Earl R. Rich

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
   D
2. ap , s
3. apt, b
4. b,mc,p
5. bb
6. Be
7. dve,pd
8. Fta
   c
9. h
10. mc , 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

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

Peter S. Dawson

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) "

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) "
    t
18. b --tawny (III) "
19. Chr--Charcoal (III) "
    d
20. b --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
D
39. r --red Berkeley
54. pd, r--paddle, red
r
55. py, r, M --pygmy, red, red modifier
59. r, sp--red spotted
61. pd, pte--paddle, platinum eye

Autosomal

63. p--pearl II New York 1976
Pk
64. p --pink II Chazy, 1959
65. p pearl II Park 1955
S
66. p pearl II
76. au--aureate III
78. b--black III
S-1
81. b -- black, Brazil
82. b--black Chicago 1955
84. b--black McGill 1959
85. b--black McGill via New York, 1976
86. b--black NASA 1959
88. b--black synthetic (Chicago/McGill)
90. Chr--Charcoal III
91. lod p--light ocular diaphragm, pearl III,II
94. msg--melanotic stink glands III
96. mt--mottled III
t
98. b --tawny III
105. fas-2--fused antennal segments-2 IV
107. ap, ju--antennapedia, juvenile urogomphi
113. s--sooty (Berkeley synthetic background) IV
114. s--sooty (New York) IV
135. j--jet V
AS
136. j --jet V

139. mc--microcephalic V Chazy, 1959
140. mc-1 microcephalic-1 (eyeless) V Hayward 1967
143. fas-3a fused antennal segments 3a V Berkeley, 1963
148. m--maroon V Purdue 1970
150. rb--ruby V Berkeley, 1962
156. Mo--Microphthalmic VI Chazy, 1959
162. sa=ca--short antenna VII Cold Sprg. Hbr. 1960
165. c--chetnut VII Purdue, 1962
168. ju-7--juvenile urogomphi VII-IV Purdue
170. ble--blistered elytra VII Berkeley 1962
173. c, Rd VII,II Corvallis 1975
S
180. ap --antennapedia VIII Berkeley 1962
D
186. sq --squint VIII Chazy 1959
189. apt--alate prothorax IX Berkeley 1963
192. ptl--prothoraxless IX Chazy 1959
194. ppas--partially pointed abdominal sternites Berk. 1963
196. mas--missing abdominal sternites II Berkeley 1964
228. Dch--Dachs II San Bernardino 1976
230. fas-1--fused antennal segments-1 Chazy 1959
233. imp--incomplete mesothoracic projections
238. mxp--maxillopedia II berkeley 1965
240. Npp--Non-punctate prothorax, a phenodeviant
245. pec--pectinate
252. sc--scar Purdue
259. w--white Purdue
261. fas-8--fused antennal segments-8
271. Gi--Giant PIL
278. la--long abdomen PIL
280. Veracruz small
288. fas-9 fused antennal segments-9 San Bernardino, 1975
295. pd,p--paddle, pearl I, II
296. pd,p,b--paddle, pearl black I, II, III
297. sp,p--spotted, pearl I, II
299. py,i,p--pygmy, ivory, pearl I, II, II
301. p, au, lod--pearl, aureate, light ocular diaphragm II, III, III.
302. p, au, mc--pearl, aureate, microcephalic II, III, V
303. p,b--pearl, black (II, III)
304. p,au,lod,msg--pearl, aureate, light ocular diaphragm, melanotic stink glands (II, III, III, III)
306. p,b,pe--pearl, black, pointed elytra (II, III,?)
308. p,mc--pearl, microcephalic II, V
310. p,s--pearl, sooty II, IV
312. p,j,Npp--pearl, jet, Non-punctate prothorax II, V
313. p,apt,Mo--pearl, alate prothorax, Microphthalmic II, II, VI.
315. p,mas--pearl, missing abdominal segments II, II
316. p, knp--pearl, knobby prothorax II, II
317. p,aa--pearl, abbreviated appendages II, V
322. p,Fas-4,b--pearl, Fused antennal segments-4, black II, ?, III
415. mxp,s--maxillopedia, sooty II, IV

416. au, s--aureate, sooty III,IV
417. h, s--hazel, sooty III, IV
428. c, Npp--chestnut, Nonpunctate prothorax VII, ?
430. au,Npp--aureate, Nonpunctate prothorax III, ?
436. au,mc--aureate, microcephalic III, V
442. Df,s,Mo--Deformed, sooty, Microphthalmic ?, IV, VI
444. i,lod,Mo--ivory, light ocular diaphragm, Microphthalmic II, III, VI
445. i,ppas-ivory, partially pointed abdom. sternites II, ?
448. Chr,ap--Charcoal, antennapedia III, VIII
450. au,ble--aureate, blistered elytra III, VII

	ELL	Pk	
454.	p	/p	II

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

V. Tribolium confusum

Wild type strains

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

Synthetic strains

1. Berkeley

Mutant strains

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

b-SSM,spl--black, split
ble--blistered elytra V
ble,e--blistered elytra, ebony V,V
car,p--carmine, pearl
cas--creased abdominal segments II
cla-claret
cru--crumpled I
dpe--dirty pearl eye II
dj--disjoined VI
dt--dent (see umb--umbilicus)
dt,p--dent, pearl
e--ebony V Chicago, 1955
(other ebony alleles)
e,fas-3--ebony, fused antennal segments-3 V, ?
e-2--ebony-2 (not allelic with e) II
e-2,fas-1--ebony, fused antennal segments-1
ele--elongated elytra
ele,fas-2--elongated elytra, fused antennal segments-2
es--eyespot I
es,fas-1--eyespot, fused antennal segments-1
es,fas,msg--eyespot, fused antennal segments melanotic stink glands I, ?, III
es,fas,sti--eyespot, fused antennal segments, sternites incomplete
eu,fas-2--extra urogomphi, fused antennal segments-2
fas-2--fused antennal segments-2 II
fas-2,lod,msg,p--fused antennal segments-2, light ocular diaphragm, melanotic stink glands, pearl II,III,III,II
fas-2,lod,p--fused antennal segments-2, light ocular diaphragm pearl II,III,II
fas-2,msg--fused antennal segments-2, melanotic stink glands II,III
fas-3--fused antennal segments-3
fro--frosted
lod,rus--light ocular diaphragm, ruby spot
msg--melanotic stink glands III
msg,rus--melanotic stink glands, ruby spot III,III
msg,twa--melanotic stink glands, twisted abdomen III,?
ov-like--overshot-like
p-pearl II
p-Slough-pearl
R
p --pearl riboflavinless II
r-red I
r,sh--red, short elytra
U
r --red
Z
r --red from Zagreb
rby--ruby
rus--ruby spot III
sh--short elytra (Berkeley)
sh,sp,twa--short elytra, split, twisted abdomen
sp--split III

sp-1--split-1
twa--twisted abdomen
thu--thumbed IV
S
thu --an allele of thu. IV
thu, Xl--thumbed, Extra large
umb--umbilicus

VI. Tribolium destructor

VII. Tribolium freemani

VIII. Tribolium madens

A. Sokoloff

South Orange, New Jersey 07079
Seton Hall University
Department of Biology

Tribolium castaneum

Wild Type Strains:

McGill Wild	via California State

Synthetic Strains:

Pearl Foundation	via Purdue University
Black Foundation	via Purdue University

Mutant Strains:

Black	via Chicago
Red^{HO}	via California State
Short antennae (Sa)	via Purdue University
Short antennae (ca)	via Oregon State
White	via California State

Tribolium confusum

Wild Type Strains:

Wild Type	via Carolina Biological Supply

Eliot Krause

SAVANNAH, GEORGIA
STORED-PRODUCT INSECTS RESEARCH AND DEVELOPMENT LABORATORY

I. Wild type strains

A. Lepidoptera

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

b. Coleoptera

1. Anthrenus flavipes LeConte	Savannah, and Durham
2. Attagenus megatoma (Fab.)	CSMA strains
3. Callosobruchus maculatus (Fab.)	Fresno, ca.
4. Cathartus quadricollis (Guerin-Meneville)	Unknown
5. Cryptolestes pusillus (Schonherr)	Tifton, Ga.
6. Dermestes maculatus De Geer	Madison, Wis.
7. Gibbium psylloides (Czenpinski)	Unknown
8. Lasioderma serricorne (Fab.)	Unknown
9. Oryzaephilus mercator (Fauvel)	Unknown
10. Oryzaephilus surinamensis (L.)	Manhattan, Kan.
11. Rhyzopertha dominica Fab.)	Unknown
12. Sitophilus granarius (L.)	Manhattan, Kan.
13. S. oryzae (L.)	Ark., Calif., Kan., La. Minn. and Tex.
14. S. zeamais Motchulsky	Estill, S.C.

15. Stegobium paniceum (L.)	Madison, Wis.
16. Tenebrio molitor (L.)	Manhattan, Ka, Durham, N.H.
17. Tenebroides mauritanicus (L.)	Savannah, Ga.
18. Tribolium castaneum (Herbst)	Unknown
19. Tribolium confusum duVal	Manhattan, Kan.
20. Tribolium madens Charpentier	Tifton, Ga.
21. Trogoderma glabrum (Herbst)	Madison, wis., Riverside, Ca.
22. T. inclusum LeConte	Madison; Riverside
23. T. variabile Ballion	Fresno, Riverside, Ca.

II. mutant strains

A. Plodia interpunctella

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

B. Tribolium castaneum.

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

C. Tribolium confusum

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

New mutants

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

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

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

R. Davis

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

1. Tribolium brevicornis (two vials)

2. Tribolium castaneum

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

3. Tribolium confusum

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

(Ed.).

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

I. Wild type strains

A. Coleoptera strains

Dermestidae

Attagenus megatoma (F.)	Madison, Wis., 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

Stock Lists

Silvanidae	
Ahasverus advena Waltl.	Field collected, Mn., 1984
Tenebrionidae	
Cyaneus angustus (LeConte)	Winnipeg; 1974.
Tribolium castaneum (Herbst) -	Field collected, Mn., 1977 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.

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

Tribolium castaneum

Wild type strains:

1. Base populations	Guelph, 1987
2. Inbreeding Line (full sib mating)	Beijing, 1988
3. Wu Line (local line)	Beijing, 1988
4. R Line	Beijing, 1990
5. H Line (selected for heavier pupa wt.)	Beijing, 1991
6. L line (selected for highter pupa wt.)	Beijing, 1991

Mutant Strains:

1. Base population maintained with no artificial selection and minimum of inbreeding	Guelph, 1987
2. Inbreeding Line (full sib mating)	Beijing, 1988

L. Zhang

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)

N	
7. antennapedia, (ap -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 Nuñez 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

Stock Lists

INDIA

NEW DELHI 110012
INDIAN AGRICULTURAL RESEARCH INSTITUTE
DIVISION OF ENTOMOLOGY

STRAIN	RESISTANCE	REARING MEDIA
Tribolium castaneum:		
1. Malathion resistant	>x 200	Common wheat flour charged with tech. malathion.
2. Lindane resistant	>x 100	Common wheat flour charged with tech. lindane
3. DDT resistant	>x 100	Common wheat flour charged with tech. DDT.
4. Pirimiphos methyl resistant	>x 18	Common wheat flour charged with tech.pirimiphos methyl
5. Phosphine resistant	x 6.3	Common wheat flour.
6. Deltamethrin	>x 1000	Common wheat flour charged with deltamethrin.
7. Susceptible	-	Common wheat flour.
8. Black mutant	-	"
Tribolium confusum:		
9. Susceptible	-	"
10. Nigrat-melanic mutant	-	"

J. D. SAXENA
SENIOR SCIENTIST

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

Stock Lists

JAPAN

TSUKUBA
STORED-PRODUCT ENTOMOLOGY LABORATORY
NATIONAL FOOD RESEARCH INSTITUTE
KANNONDAI 1-2-1,
TSUKUBA, IBARAKI 305

PSOCOPTERA

Liposcelidae

1.	*Liposcelis bostrychophilus* Badonel	Wild
2.	*Liposcelis entomophilus* (Enderlein)	Wild

Trogiidae

3.	*Lepinotus reticulatus* Enderlein	Wild

COLEOPTERA

Silvanidae

4.	*Oryzaephilus surinamensis* (L.)	Wild

Cucujidae

5.	*Cryptolestes turcicus* (Grouvelle)	Wild
6.	*Cryptolestes pusilloides* (Steel and Howe)	Wild (Okayama)

Tenebrionidae

7.	*Alphitobius diaperinus* (Panzer)	Wild
8.	*Gnathocerus cornutus* (Fabricius)	Wild
9.	*Latheticus oryzae* Waterhouse	Wild
10.	*Palorus ratzeburgi* (Wissmann)	Wild
11.	*Tribolium castaneum* (Herbst)	Wild
12.	*Tribolium confusum* Jacquelin du Val	Wild
13.	*Tribolium freemani* Hinton	Wild
14.	*Tenebrio molitor* L.	Wild
15.	*Tenebrio obscurus* Fabricius	Wild

Anobiidae

16.	*Lasioderma serricorne* (Fabricius)	Wild
17.	*Stegobium paniceum* (L.)	Wild

Ptinidae

18.	*Gibbium equinoctiale* Boieldieu	Wild

Bostrichidae

19.	*Rhyzopertha dominica* (Fabricius)	Wild
20.	*Dinoderus minutus* (Fabricius)	Wild

Curculionidae

21.	*Sitophilus oryzae* (L.)	Wild
22.	*S. zeamais* Motschulsky	Wild

LEPIDOPTERA

Phycitidae

23.	*Ephestia elutella* (Hubner)	Wild
24-1.	*Ephestia cautella* (Walker)	Wild
24-2.		brbr (brown wing)
25-1.	*E. kuhniella* (Zeller)	Wild
	Mutant:	
25-2	aa (Red, Misima)	
25-3	bb (black wing mutant	
25-4	wawa (white eyes	
26.1	*Plodia interpunctella* (Hubner)	Wild

Gelechiidae

27.	*Sitotroga cerealella* (Olivier)	Wild

HYMENOPTERA

Ichneumonidae

28.	*Ventris canescens* (Gravenhorst)	Wild

O. Imura
T. Kotaki

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

Stock Lists

OKAYAMA
LABORATORY OF APPLIED ENTOMOLOGY
COLLEGE OF AGRICULTURE
OKAYAMA UNIVERSITY

1. Wild type strains

COLEOPTERA

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

HYMENOPTERA

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

Toshiharu Yoshida

INSTITUTE OF BIOLOGICAL SCIENCES
UNIVERSITY OF TSUKUBA
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 C Hirosaki, Japan
1
jC Kyoto, Japan, 1936
mC Morioka, Japan
nC Niigata, Japan, 1964
pC Punjab, India
sC Shuzenji black mutant
bl
tC Tokyo (Nishigahara, Nat. Inst. Agr.), Japan
t C Tsukuba, Japan
a
t C Tsukuba, Japan
a 2
t C Tsukuba, Japan
s
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 (0C)
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 ? w	Purdue	
58.	wine r 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 Pk	Sokoloff,	1977
66.	pink p 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

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			
Alphasverus advena (Waltl)	Insectary	W. Africa	1956
Alphitobius diaperinus (Panz)	Insectary		
	Goose's foot	Britain	1983
	Droxford	Britain	1984
	35	Britain	1987
Anthrenocerus australis (Hope)	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 Halstead & Green	Finland Sweden		1965 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 strains 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.)			

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 *L. subfuscus* (Broadhead)		Britain	1949
Trogium pulsatorium		Britain	

Stock Lists

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 (pe) X	O-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

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POST HARVEST PESTS AND QUALITY SECTION

A. COLEOPTERA

Anobiidae

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

Bostrichidae

1. Dinoderus distinctus
   a. Tanzania
2. D. minutus
   a. Indonesia
3. D. porcellus
   a. Togo
4. Prostephanus truncatus
   a. Costa Rica
   b. Mexico (3 strains)
   c. Nigeria
   d. Tanzania (4 strains)
   e. Togo
5. Rhyzopertha dominica
   a. Ex-MAFF (2 cultures)
   b. Angola (2 strains)*
   c. Botswana*
   d. Brazil*
   e. Ethiopia (2 strains)**
   f. Ghana*
   g. India*
   h. Kenya (4 strains)****
   i. Mali (3 strains)**
   j. Morocco (2 strains)**
   k. Nepal
   l. Pakistan (2 strains)**
   m. Philippines (2 strains)**
   n. Sri Lanka
   o. Thailand (2 strains)
   p. Zimbabwe*
   q. Unknown

Bruchidae

1. Acanthoscelides obtectus
   a. Australia
   b. Colombia (2 strains)
   c. Uganda
   d. Zimbabwe
2. Callosobruchus analis
   a. Ex-MAFF
3. C. chinensis
   a. Indonesia
4. C. maculatus
   a. Brazil
   b. Uganda
5. C. rhodesianus
   a. Zimbabwe
6. Caryedon serratus
   a. India
7. Zabrotes subfasciatus
   a. Colombia (2 strains)
   b. Uganda

Curculionidae
1. Sitophilus sp
   a. Mexico
   b. Philippines
   c. Sudan
   d. Thailand
   e. Zambia
   f. Zimbabwe (2 strains)
2. S. granarius
   a. Ex-MAFF (2 cultures)
3. S. oryzae
   i. Normal strains
      a. Ex-MAFF
      b. Brazil
      c. Philippines
      d. India (2 strains)
      e. Indonesia
      f. Morocco
      g. Windsor (UK)*
      h. Zimbabwe
   ii. Pulse-feeding
      a. Burma
4. S. zeamais
   a. Ex-MAFF
   b. India
   c. Mali
   d. Tanzania (2 strains)
   e. Thailand (2 strains)
   f. Togo
   g. Zimbabwe (5 strains)*

Dermestidae
1. Dermestes ater
   a. Ex-MAFF
2. D. maculatus
   a. Jamaica
3. Trogoderma granarium
   a. India
   b. Sudan

Histeridae
1. Teretriosoma nigrescens
   a. Mexico

Lophocateridae
1. Lophocateres pusillus
   a. Philippines

Silvanidae
1. Ahasverus advena
   a. Ex-MAFF
2. Oryzaephilus sp
   a. Kenya (3 strains)
3. O. surinamensis
   a. Ex-MAFF

Tenebrionidae

1. Tribolium sp	a. Thailand
	b. Zambia
2. T. confusum	a. Ex-MAFF
3. T. castaneum	a. Ex-MAFF
	b. Botswana*
	c. Brazil
	d. India*
	e. Indonesia (3 strains)
	f. Kenya (2 strains)#
	g. Mali (4 strains)**
	h. Mozambique
	i. Pakistan (2 strains)**
	j. Philippines (3 strains)+
	k. Sri Lanka*
	l. Sudan
	m. Thailand (4 strains)* +
	n. Zambia (3 strains)
	o. Zimbabwe (6 strains)**
	p. Unknown
4. Latheticus oryzae	a. Ex-MAFF
5. Gnatocerus cornutus	a. Ex-MAFF
6. Palorus subdepressus	a. Ex-MAFF

Key
* Number of strains which have to date been found to be Phosphine resistant.
+ Malathion resistance noted.
# Pirimiphos methyl resistance noted.

B. LEPIDOPTERA

Pyralidae

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

Gelechiidae

1. Sitotroga cerealella	a. Sudan

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RESEARCH, TEACHING AND TECHNICAL NOTES

A NOTE ON BASE POPULATION PARAMETERS IN TRIBOLIUM CASTANEUM

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I.V.R.I., IZATNAGAR 243 122 (U.P.)

The present experiment was carried out to study the inheritance of fecundity traits (egg number and hatchability) and developmental traits (pupation time and emergence time) in a population of Tribolium castaneum. The population used in this investigation was established at Population Genetics Laboratory, I.V.R.I., Izatnagar, U.P., India by collecting beetles from flour mills in Izatnagar and random mating them for 10 generations. The culture media consisted of 95 parts whole wheat flour, 4 parts dried yeast powder and 1 part vitamin mixture (A, B2 and D3). The cultures were maintained in a B.O.D. incubator at a temperature of 31 ± 0.5 and a relative humidity of 70 ± 5 per cent. The larvae were checked for pupation from 10th day onwards and the pupae were sexed.

A total number of 50 males and 200 virgin females (atleast 6 days old) were raised from the main stock, and each male was mated to 4 females by putting them together in a vial with sufficient medium for about 6 days. The eggs produced over a period of 24 hours by each female were collected and transferred to fresh vials with fresh medium and incubated. The larvae from each these vials after 10 days of incubation were counted. The number of larvae expressed as the per cent of the number of eggs

incubated was reckoned as the hatchability per cent. The larvae were transferred to individual vials. These vials were checked for pupation after 13th day onwards and later for emergence. Both pupation time and emergence time for individual progeny were recorded. Altogether 1159 beetles were scored for pupation time and emergence time, while egg production and hatchability were recorded for 338 beetles. The averages and standard errors for different traits were calculated. The heritability estimates for different traits and genetic, phenotypic and environmental correlations among them were also estimated.

The averages, standard errors and coefficients of variation for different traits are given in Table 1. The averages of pupation time (14.61 days) and emergence time (19.39 days) were shorter than those reported by Young (1970) and Wade (1978). The average number of eggs produced over a period of 24 hours (11.62) was similar to the report of Campo and Rodriguez (1985). Average hatchability percentage (68.16) was lower than the value reported by Bartlett (1962). The lower values of pupation time, emergence time and hatchability per cent in the present study might be due to genetic differences in the strains, daily handling of larvae from 13th day onwards and to a minor extent to the differences in the environmental conditions. The lower hatchability could also be due to the fact that only those larvae surviving upto 10th day were reckoned for calculating the hatchability percentage.

The Least squares analysis of variance showed that both pupation time and emergence time were not influenced by ~~the~~ sex.

However, females took a slightly longer time both to pupate and emerge as compared to males.

The heritability estimates for the traits studied are given in Table 2. The heritability values were higher for pupation time (0.554 to 0.748), emergence time (0.493 to 0.812) and hatchability percentage (0.580) while it was lower for egg number (0.176). The estimates of heritability for pupation and emergence time were slightly higher than those reported by Sokoloff (1977). The higher estimates of heritability from dam components of variance than those from sire components of variance revealed that both pupation and emergence time are influenced to a certain extent, by maternal and dominance effects. Dawson (1965) also observed that 15, 8 and 21 per cent of variation in pupation time could be attributed to additive genetic, maternal and dominance effects, respectively. The heritability values for egg production reported by Verma (1977) and Campo and Rodriguez (1985) were higher than the estimates in the present study showing the variation among different strains with regard to influence of additive genetic effects.

The correlations between different traits are given in Table 3. Pupation time had high and positive genetic, phenotypic and environmental correlations with emergence time. This is expected, as emergence time is the sum of pupation time and pupal period. The genetic and phenotypic correlations between egg number and hatchability were very low.

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Table 1 : Averages of different traits in the base population

Traits	Number of observations	Mean	S.E.	C.V.
Pupation time (days)	1159	14.61	0.03	6.58
Emergence time (days)	1159	19.39	0.03	4.83
Egg number	338	11.62	0.27	42.28
Hatchability (%)	338	68.16	1.44	38.84

Table 2 : Heritability values for different traits in base population

Traits	Sire components	S.E.	Dam components	S.E.	Sire + Dam components	S.E.
Pupation time	0.554	0.186	0.748	0.148	0.651	0.105
Emergence time	0.493	0.178	0.812	0.156	0.652	0.103
Egg number	0.176	0.147	-	-	-	-
Hatchability percentage	0.580	0.202	-	-	-	-

Table 3 : Correlations between pupation time and emergence time and egg number and hatchability in the base population.

Traits	Correlations		
	Genetic	Environmental	Phenotypic
Pupation - Emergence time	-	-	0.87+0.02
Sire component	0.91+0.04	0.77	-
Dam component	0.99+0.00	0.59	-
Sire + Dam component	0.96+0.00	0.83	-
Egg number - Hatchability	0.25+0.36	-0.03	0.04+0.05

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*Effects of overcrowding on Tribolium freemani adults and larvae.

When Tribolium cultures in vials are overcrowded, a series of ecological changes may take place, eventually leading to a loss of that culture. These successive changes can be summarized as follows:

1. There is an increase in moisture. In an air conditioned lab, this moisture condenses on the inner surface of the walls of a glass container (a vial or half-pint bottle).

2. The condensed water droplets begin to combine with flour particles, forming a glue.

3. When the proper moisture level is reached, mold begins to develop.

4. The mold may trap all stages of the flour beetle, resulting in their death. The dead larvae and adults begin to decay. The survivors are driven to the surface of the medium.

5. Some of the adults and larvae, in search of food, may dig tunnels in the flour.

6. Decomposition of the dead bodies may result in the release of ammonia which is toxic to the beetles.

7. Some of the larvae or adults may be trapped by the fungal mycelia, and they die in the tunnels. Other larvae may scavenge on the dead bodies of larvae or adults.

8. If there are no dead bodies of imagoes, the larvae undergo lysis of their internal tissues.

9. If there are dead or dying imagoes, they may release quinones, which may cause the death of other beetles as well as the fungi.

10. The flour may turn to a black liquid, or the flour may turn sticky.

11. Gradually the flour begins to dry, forming a plug which detaches from the inner walls of the container. As this plug continues to lose moisture, eventually it forms a solid dry plug.

These changes in the flour are so characteristic that we asked a student to try to identify the microorganisms in a vial whose contents had turned liquid and black. A while later she reported

that the material did not contain any live microorganisms (bacteria, yeasts, or fungi) nor spores of any kind. This was strange, because mold will grow at least at some point in the destruction of the beetle culture, so that there should be at least some spores and/or bacteria. On the other hand, if adult beetles are present in such cultures, it is possible that when they are trapped or when they die that the quinones in the reservoir of their odoriferous glands are released, and oxidize everything they come in contact with. This may explain why the attempts at the culturing of the contents by the student assistant produced negative results.

This report summarizes the experiments carried out to explain the ecological changes which occurred in these vials.

Materials and Methods. The organisms used in these experiments were last instar larvae and adults of Tribolium freemani (because at the time they were available in large numbers). The experiment was set up on 5/21/93.

There were two sets of 1 dram (5 cc) vials, one set containing larvae only and the other adults only. All of the vials contained 1 gram of unbleached wheat flour. The larvae and adults were introduced at densities of 25, 50, 75, 100, 150, 200, 250 per gram. There were 10 replicates for the densities 25-100 per gram, and only 5 replicates for the densities of 150-250 per gram.

The two sets of vials were introduced into a walk-in incubator maintained at 30° C. Humidity was not controlled in the incubator.

Each week the changes in the vials were recorded. If there were microorganisms evident in the vials, preliminary identification was attempted of the cultures of these organisms. The experiment was terminated about three months after it was begun.

Results. The complete results will be published elsewhere. We give here an overview of the results of vials containing larvae and adults separately.

1. **Vials containing larvae.** The vials containing 100, 150, 200, and 250 larvae/gram failed to yield any survivors at the end of three months. Those started with 25, 50, and 75 larvae/gram of flour produced descending numbers of survivors as density increased. The overall survivor values (adults, pupae, and larvae) were 54% for density 25/gram, 36% for density 50/gram, and 33% for density 75/gram. With one exception in density 75, none of the vials containing 25, 50 or 75 larvae/vial developed any mycelia, nor did the medium become compact, solid or damp. All of the remaining densities (100-250 larvae/vial) developed mycelial plugs

(with the exception of 3 replicates in density 100), which became compact and solid. The larvae died within the medium.

2. **Vials containing adults.** Only adults in densities 25 and 50/gram survived. In the density of 25/gram some adults died, and there were some larval progeny among the survivors. At density 50/gram there were fewer larvae, and overall 54% of the adults survived. In the remaining densities (75, 100, 150, 200, and 250), all of the adults died.

The medium was granular at the top and compacted at the bottom in all densities (100-250) for the first two weeks. In the next four weeks the medium became solid and damp, and some mycelial growth was noted. Some of the populations were active, but others became sluggish.

By the time two weeks had elapsed, the food level had been reduced and probably consisted of fecal matter (it had a grayish granular appearance). The densities of 200 and 250/gram had become very damp and had a dark brown color. The beetles were "swimming" through a rather thick medium. Some fungal growth was visible under 30X magnification.

At the end of a month some of the cultures started drying out. There was no apparent food source except for some fungal growth around the inside surface of the vial, but beetles were still active. Two weeks later there was no longer any evidence of mycelial growth in most vials, and most of the adults were dead. In the density 200/gram vials, the medium had formed a plug in one vial, and in another vial the plug was extremely damp and black. In the density 250 vials there were two vials that had black plugs. This was at the last observation on 7/15/93.

Discussion. It is clear that as density increased, there was also an increase in dampness because of the release of moisture by the beetles. This increase in moisture, generated by the larvae and adults, may have (with few exceptions) a deadly effect on the larvae because the development of mycelial growth in the presence of such moisture may trap the larvae. Apparently the larvae which survive longest under these conditions will be those who have crawled to the surface of the medium.

Larvae living in the non-damp media were able to survive. It may be noted that stink glands do not develop until the pupal stage, so that larvae cannot sterilize the medium against fungi.

The adults were also affected by an increase in moisture at the high densities as evidenced by the fact that the medium formed a plug. The "plug" is identical in the larval and adult vials. However, once the plug is formed, the adults can still break it down and use it as food. (It is noteworthy that in high adult

density vials many of the dead beetles were represented by body fragments, the remains of scavenging activities of the survivors. As density increased, the scavenging activities of the survivors increased, judging from the number of dead beetles reduced to fragments.)

The adults in the high density vials apparently did not attempt to release their quinones. Had they done so, the confined atmosphere in the vial would surely have changed the air contents to a gas chamber and killed the beetles. When last examined, the high density vials contained a few live adults and even a few small larvae.

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* Gamma Irradiation of the Flour Beetle, *Tribolium anaphe* Hinton (Coleoptera: Tenebrionidae): Effects of Puparial Age on the Reproductive Ability.

The flour beetle, *Tribolium anaphe* Hinton in one of the most destructive pest infesting grains and their products throughout the many countries. In an attempt to suppress and control insect pest populations infested stored products, several methods and techniques are being used, e.g. chemical control, temperature treatment, fumigation and so on. However, because of insecticide resistance, gamma radiation appears to be a potential alternative to these for insect control in stored products (Hasan *et al* 1989; Navon *et al.* 1988; Mehta *et al.*, 1990; Sengonca & Schade and Saxena *et al.*, 1992). Comparative studies of radiation sensitivity among stored product insect pests are important for radiation control because the sensitivity varies depending on the stages and ages (Lee & Ducoff, 1983; Williamson *et al.*, 1985; Ishii *et al.*, 1986 and Ducoff, 1986). Although the irradiation effects on the various aspects of *Tribolium* spp. have been reported by several authors (Corks, 1957; Sokoloff, 1961; Yang, 1973; Mckibben de Conconi, 1978; Bonginwar *et al.*, 1981; Wool, 1982 and Cheng & Ducoff, 1989). However, a literature survey concerning the radiation effects revealed that a very little is discussed with *T. anaphe* sp. specially on the reproductive potential. So, therefore, in the present paper the effects of gamma radiation on the reproductive ability of *T. anaphe* emerged from the various ages irradiated pupae, are described.

The pupae of *T. anaphe* used in this study were obtained from the laboratory stock cultures reared in glass jars (20 X 10 cm) on the complete diet described by Park and Frank (1948). The gamma radiation (Co^{60}) was exposed to the various ages pupae such as 1-, 2-, 3- and 4-day old and the doses were 0 (control), 1-, 2-, 4- and 6-krad. After exposed, the pupae were kept separately in sex and age wise in an incubator for eclosion. After eclosion, they were paired sexwise and put in a vial (3.4 X 1.8 cm) containing wholemeal flour for oviposition. The eggs were counted by sieving the contents at 3-days intervals for 45-days.

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The percent of reproductive control (PRC) was calculated as follows (Rizvi *et al.*, 1980):

$$PRC = \frac{(V_1 - V_2)}{V_1} \times 100$$

where V_1 = eggs laid by the control females and V_2 = eggs laid by the treated females. Eggs were also observed for their fertility . Here fertility has been defined as the percentage of first instar larvae that emerged from am accurately known number of eggs (Park *et al.*, 1961). Each treatment was comprised with 15 pairs of adult in each age and dose for the oviposition. The adults failed to emerge from the pupae irradiated at 6-krad in all the age groups. A very few eclosed adult was also observed in 1-day pupae irradiated at 2- and 4-krad doses. So, it was not possible to continue the experiments at these treatments with the parameters considered.

The sources of radiation used in the present experiments was the gamma Co^{60} and 12 krad/hr at 30 cm distance from the middle of the source pencil. The selection of radiation dose was based on its effectiveness against *Tribolium* spp. (Hasan *et al.*, 1989 and Mehta *et al.*, 1990). All the experiments were carried out in an incubator at 30 ^{0}C throughout the investigations.

The results showed that gamma radiation affects drastically the fecundity and fertility of *T. anaphe* adults emerged from the various ages pupae (**fig 1**). The fecundity was decreased gradually in increasing the doses. The same sequence was also observed in the fertility. The d-values indicated that there are significant variation between the corresponding control of each age and dose (**table 1**). The adults emerged from the 1 day old pupae became moribund and died within 4-5 days of its emergence when exposed at 2- and 4-krad.

Data concerning the sensibility indicated that younger pupae were more sensibility to gamma radiation than the older pupae. The radio-sensitivity was also decreased in increasing ages. The sequence of the susceptibility among the ages was 1 > 2 > 3 > 4 day old pupae. The number of progeny per female abruptly declined from 2 krad to 4 krad in all the age groups (**fig 1**). The reduction in number of progeny was great at 4 krad dose level. North and Holt (1970, 1971) reported that the reduced fecundity in any insects may cause of reduced transfer of active sperms by treated males to untreated females and to limited production of oocytes in the developing female

The results further indicated that the doses used in the experiments did not show any of the complete sterility either in the male or female which is in agreement with those of Banham & Cork (1966). Von Borstel (1968) also reported that the fertility from the irradiated larvae support the general statement that the egg cells are more sensitive

to radiation than sperm and spermatocytes. The magnitude of the radiation effect on *Tribolium* is influenced by the dose and age at exposure (Ducoff, 1975). A previous work by Begum et al. (1985) has shown that the sensitiveness of *Callosobruchus analis* to certain gamma doses are positively correlated with increased ages which also supports the result of the present investigation.

Reviewing the present results and the previous works (Lee & Ducoff, 1983; Williamson *et al.*, 1985; Ishii *et al.*, 1986), it may be concluded that the age plays an important role in influencing the sensibility of stored product insects to gamma irradiation.

Age of pupae *(days)*	1 krad		2 krad		4 krad	
	d*-values	PRC**	d-values	PRC	d-values	PRC
1	8.14	28.16	-	-	-	-
2	7.08	24.93	5.41	79.49	4.83	88.87
3	6.91	25.74	7.79	78.05	7.12	83.34
4	6.26	8.61	5.34	54.88	6.14	68.52

* d=Normal standard deviate, ** PRC = Percent Reproductive Control
- Adults not survived

Table 1: **Showing the values of normal standard deviate and percent reproductive control of *T. anaphe* adults emerged from the various ages irradiated pupae.**

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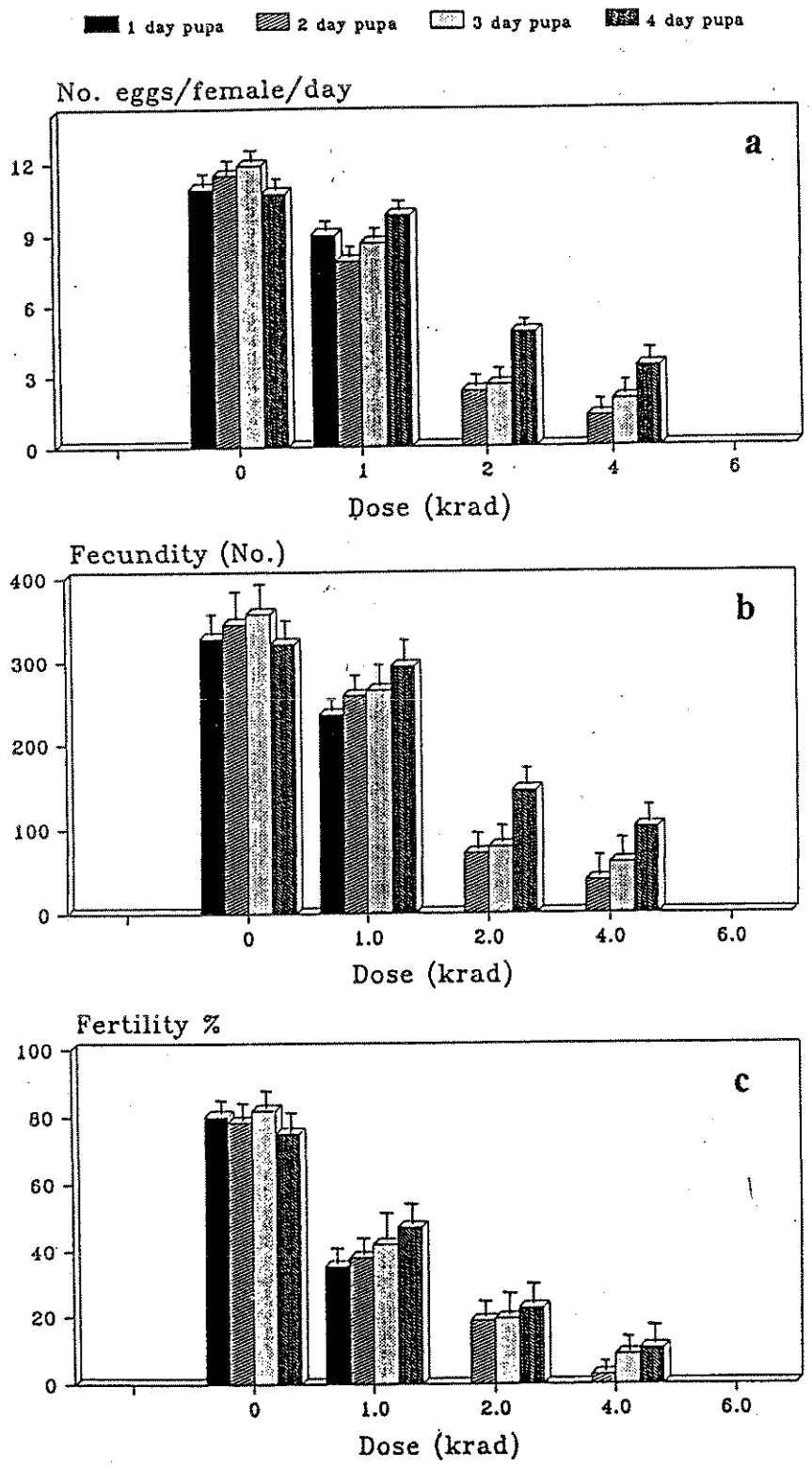

Fig 1: **Effect of gamma irradiation on the number of eggs per female/day (a), mean fecundity (b) and fertility (c) of *T. anaphe* treated as various ages pupae. Line on the top of the bar indicates the abosulate values of standard deviation.**

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* A Preliminary Note on the Biology of Some *Tribolium* Species (Coleoptera: Tenebrionidae).

Flour beetles of the genus *Tribolium* include a large number of species feeding on a variety of stored commodities throughout the world (Sokoloff, 1972). They are useful experimental tools which have been used in classic studies of the biology of ageing. They are easy to culture in large numbers and require no sophisticated equipment for maintenance. However, the biology of this genus varies greatly from one species to another (Chapman, 1924; Frost *et al.*, 1944; Reynolds, 1945; Cashman, 1951; Magis,1954a ; Khalifa & Badawy, 1955b; de Faria Estacio, 1956; Howe, 1956; Sang, 1959; Naylor, 1964; House, 1965; Sokoloff *et al.*, 1966b; Gordon, 1968). The culture media is one of the main factors which controls the rate of development of *Tribolium* throughout ontogeny (Park and Frank, 1948; Magis, 1963; Sokoloff *et al.* 1966a). Many sorts of media have been used by entomologists to maintain *Tribolium* cultures, though standard media have been established for the culture of both *T. confusum* and T. *castaneum* (Park and Frank, 1948). However there is a lack of published data describing food media suitable for the culture of other *Tribolium* species. The present paper is an attempt to determine the effect of specific food media on the biology of some *Tribolium* species, i.e. *T. anaphe* Hinton, *T. brevicornis* Leconte, *T. castaneum* Herbst, *T. destructor* Uyttenb, *T. freemani* Hinton in detail.

Beetles of the *Tribolium* species used in the present experiments were originally received from the Slough Laboratories, MAFF and were cultured using the following food media:

Species	Food media	Ratios
T. anaphe	wheat feed : fishmeal : yeast	8 : 4 : 1
T. brevicornis	rolled oats : wheatfeed : fishmeal : yeast	20 : 20 : 1 : 1
T. castaneum	wholemeal : yeast	19 : 1[a]
T. destructor	wheatfeed : yeast	12 : 1
T. freemani	wholemeal flour : yeast	11 : 1

[a] Park and Frank, 1948

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The food media were sterilized for six-hours at 120^{0}C and not used until at least 15 days after sterilization to stabilize moisture content and to equilibrate with the environment. Each jar was subcultured every three months to remove dead insects and exhausted medium. The cultures were kept in 3 lb. kilner jars previously sterilized at 180 ^{0}C. Some crumpled filter papers were placed inside each jars for easy movement of the insects and the jars covered at the top with antibacterial filter papers.

Some beetles of each species were taken from the culture and kept in a petri dish for oviposition. The eggs were collected on the following day using the method of Khan and Selman (1981) and kept in a petri dish for hatching. After hatching, 200 neonate larvae of each species were collected with a fine camel hair brush and transferred to the respective food media in a 2 lb kilner jar. After ten days, the larvae of each species were weighed and their length and headcapsule width measured using an occulo micrometer. The mature larvae were also weighed and measured. After pupation, the larval periods were recorded. The pupae were sexed using the exogenital processes of the female (Halstead, 1963) and weighed . After eclosion, the pupal periods were recorded and the adults weighed. After ten days, the adults of each species were paired and placed in a glass vial (2.5 x 5 cm) containing the respective food medium. The eggs were sieved off at 3 day intervals for 30 days and kept in a petri dish to record the fertility rate. The length and width of the eggs were also measured. All the experiments were conducted in an incubator at 27 ^{0}C and uncontrolled relative humidity.

The data on the biology of *Tribolium* species cultured with different media are shown in Figs1-4. The maximum 10 day larval weight of 0.41 mg was found in *T. destructor* followed by *T. anaphe* > *T. brevicornis* > *T. freemani* > *T. castaneum* (Fig.1a). However, these trends changed in the mature stage where the maximum larval weight was recorded in *T. brevicornis* followed by *T. destructor* > *T. freemani* > *T. anaphe* > T. *castaneum* (Fig.2a). Khan & Hasan (1990) and Hasan & Khan (1988) also observed a 4.54 mg mature larval weight in *T. anaphe* reared at 30 ^{0}C. Rich and Bell (1982) recorded 1.45 mg for 21 day larval weight in *T. brevicornis* using standard food media which does not support the present results , however, this difference may be due to the use of different food media. In the present results, a maximum larval weight of 16.98 mg was recorded in *T. brevicornis* (Fig.2a). Larval length and headcapsule width also varied significantly both for the 10 day and mature larvae (Fig 1b,c; Fig 2b,c).

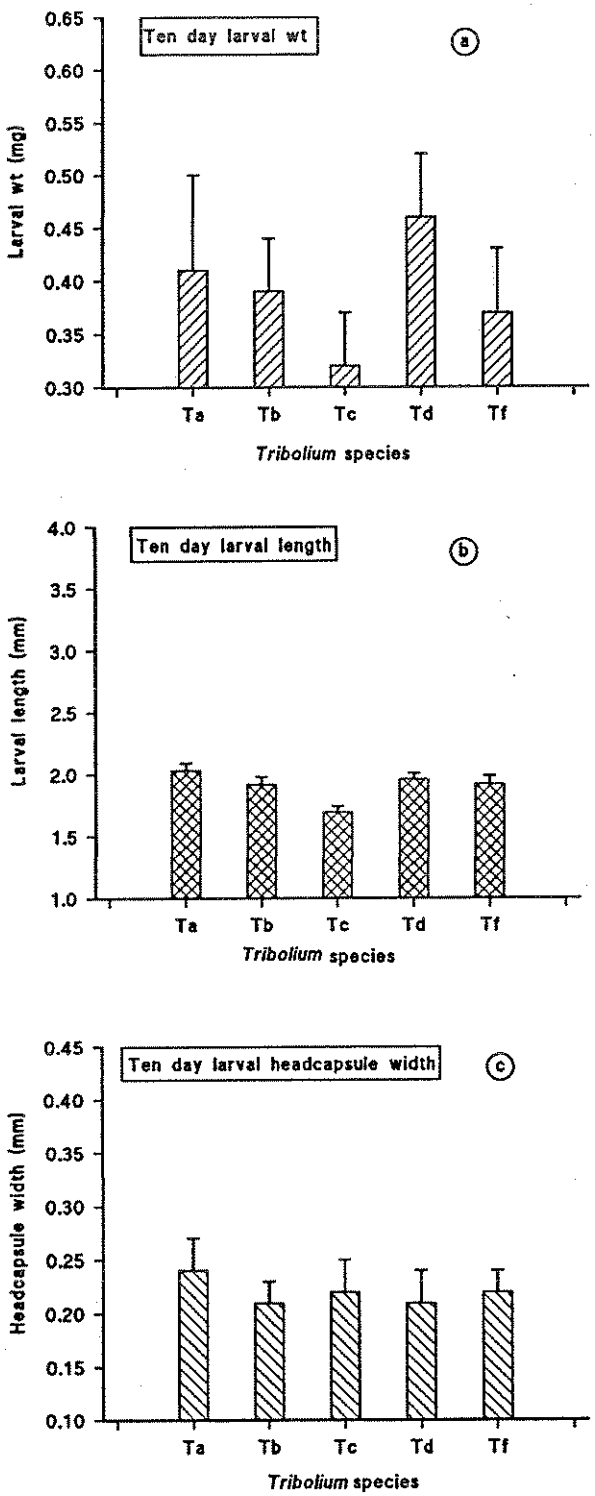

Fig 1: (a) Ten day larval weight, (b) length and (c) headcapsule width of different *Tribolium* species (Ta - *T. anaphe*, Tb - *T. brevicornis*, Tc - *T. castaneum*, Td - *T. destructor*, Tf - *T. freemani*) (Line bars indicate the SD).

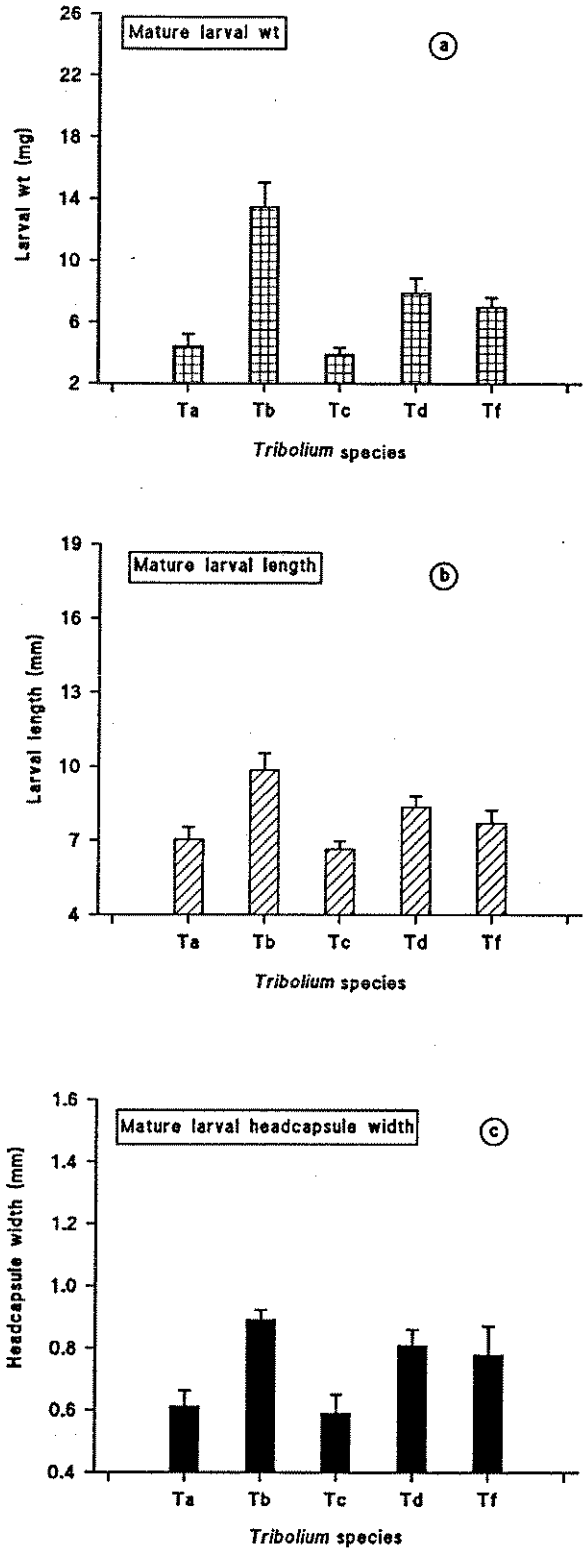

Fig 2: (a) Mature larval weight, (b) length and (c) headcapsule width of different *Tribolium* species (Ta - *T. anaphe*, Tb - *T. brevicornis*, Tc - *T. castaneum*, Td - *T. destructor*, Tf - *T. freemani*) (Line bars indicate the SD).

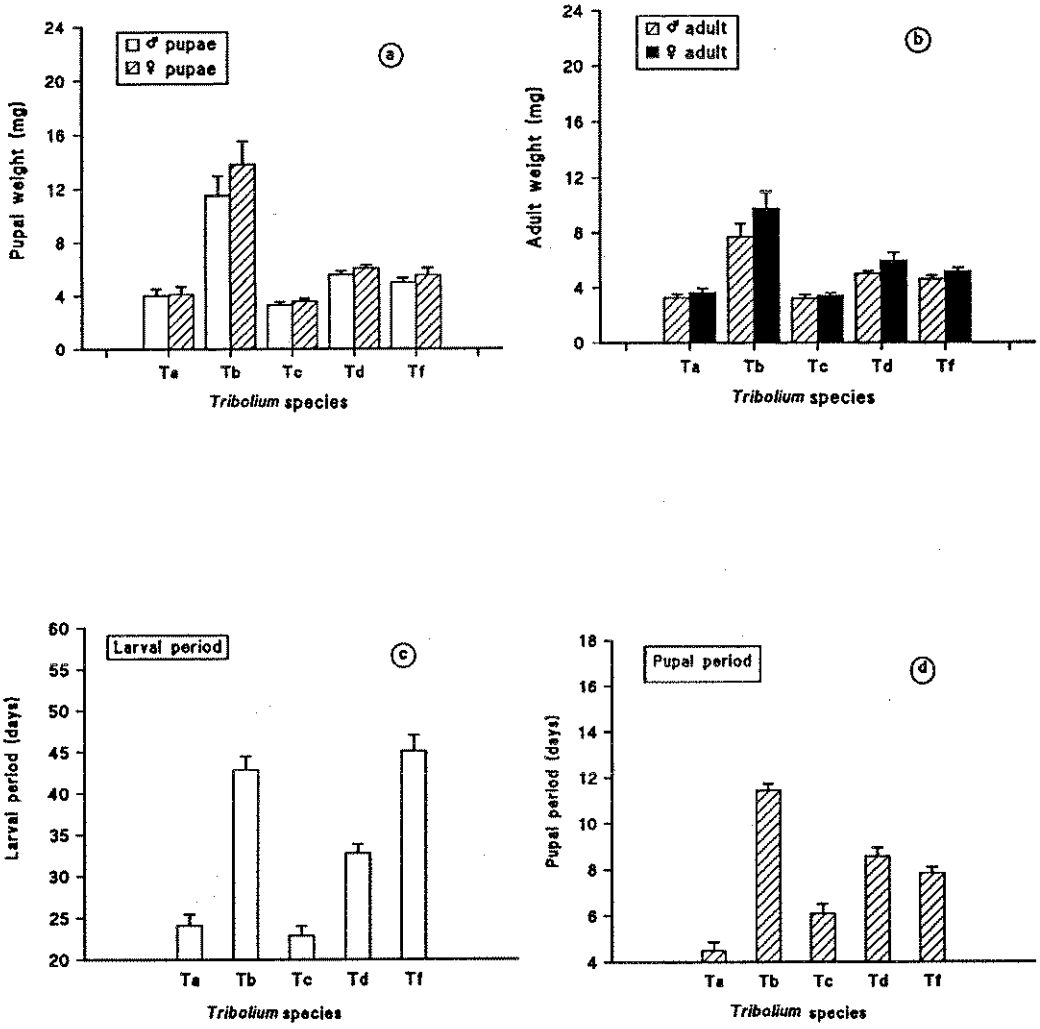

Fig 3: (a) Pupal, (b) adult weight and (c) larval (d) pupal periods of different *Tribolium* species (Ta - *T. anaphe*, Tb - *T. brevicornis*, Tc - *T. castaneum*, Td - *T. destructor*, Tf - *T. freemani*) (Line bars indicate the SD).

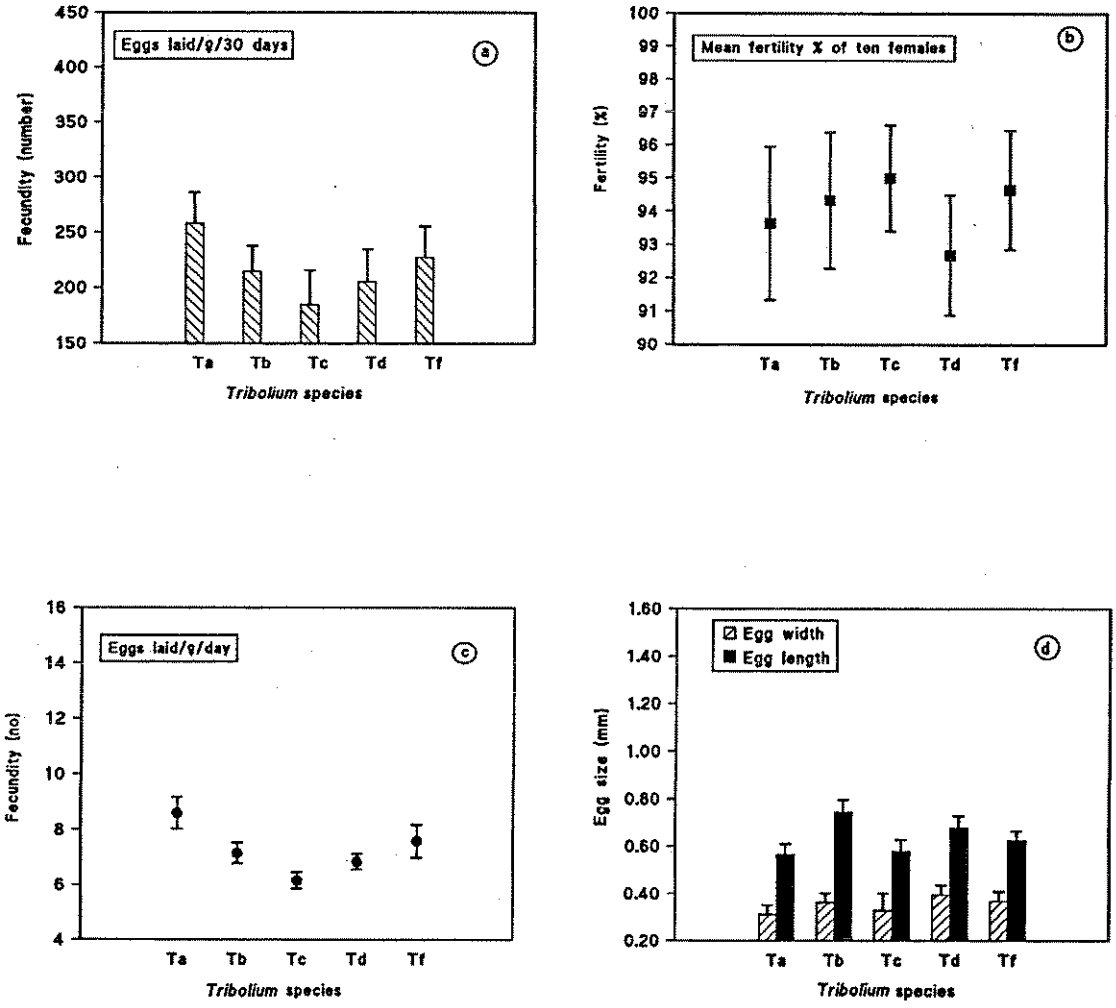

Fig 4: (a) Fecundity, (b) fertility, (c) eggs laid/female/day and (d) egg size of different *Tribolium* species (Ta - *T. anaphe*, Tb - *T. brevicornis*, Tc - *T. castaneum*, Td - *T. destructor*, Tf - *T. freemani*) (Line bars indicate the SD).

Within species the pupal and adult weight also varied between the sexes and these corresponded with their larval weight (Fig. 3a, b). The female was heavier than the male in all stages. These results are in close conformity with the findings of Nakakita *et al* (1981). The maximum larval period of 45.08 days was recorded in *T. freemani* followed by *T. brevicornis* > *T. destructor* > *T. anaphe* > *T. castaneum* (Fig. 3c). Sokoloff (1992) recorded a 41.65 (24^0C, 50% rh) day larval period for *T. brevicornis*. Nakakita *et al* (1981), Hasan & Khan (1988), Khan & Hasan (1990) and Magis (1954) observed 33.8 (30^0C, 22% rh), 17.91 (30^0C, 85% rh), 20.06 (30^0C, 82% rh) and 34.00 (27^0C, 70% rh) day larval periods in *T. freemani, T. anaphe, T. castaneum* and *T. destructor* respectively using a different range of culture media. However, the pupal periods did not follow the same trends as the larval periods. The maximum pupal period recorded was 11.45 days in *T. brevicornis* followed by *T. destructor* > *T. freemani* > *T. castaneum* > *T. anaphe* (Fig 3d). Sokoloff (1992), Nakakita *et al.* (1981) and Hasan & Khan (1988b) recorded 12.15 (24 ^{0}C, 50% rh), 7.3 (30^0C, 22% rh) and 4.42 (30^0C, 70% rh) day pupal periods in *T. brevicornis, T. freemani* and *T. anaphe* respectively using different food media. Mathlein (1943) also noted a 31 day larval and a 9 day pupal period in *T. destructor* at 28 ^{0}C and 70-80% rh.

The maximum reproductive potential of 8.60 eggs/female/day was found in *T. anaphe* followed by *T. freemani* > *T. brevicornis* > T. *destructor* > *T. castaneum* (Fig 4a). However, Khan (1981) recorded 3.47 eggs laid / female / day in *T. castaneum* using a standard food media (Park and Frank, 1948). The highest fertility was found in *T. castaneum* and the lowest in *T. destructor* (Fig 4b). Howe (1962a) and Nakakita *et al.* (1981) found the fertility percentage in *T. castaneum and T. freemani* to be 95% (27.5^0C, 70% rh) and 92% ($30\ ^0$C, 22% rh) respectively. The longest egg was *T. brevicornis* followed by *T. destructor* > *T. freemani* > *T. castaneum* > *T. anaphe* (Fig 4d). However, the egg width is not proportional to length where *T. destructor* >*T. freemani* > *T. brevicornis* > *T. castaneum* > *T. anaphe* (Fig 4d). Brindley (1930), de Fraria Estacio (1956) and Khan (1981) also found that the egg size of some *Tribolium* species showed a significant variation between each species.

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⁎Insecticidal properties of five plant materials on two strains of Tribolium castaneum (Herbst).

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ABSTRACT

The powder seed of Annona squamosa Linn. and the ground leaves of Vitex negundo Linn. were found to be toxic to FSS2 and CTC12 eggs of T. castaneum. The powder seed of A. squamosa and ground twigs of Polygonum hydropiper Linn. were toxic to the larvae and pupae of susceptible and malathion resistant strains of T. castaneum. None of the tested plant materials including Aphanomixis polystacha Wall and Sapindus mukorosis Gartn in crude powder form were able to kill either of the adult insects for any of the strains at the highest concentration (1200 ppm).

INTRODUCTION

Tribolium castaneum commonly referred to as the "red flour beetle" is a major pest of stored products (Hill, 1990). The occurrence of malathion resistance in T. castaneum has been reported in almost every strains (Dyte & Black, 1972) and thus incouraged the search for insecticidal action in plant products. Five different plant materials (in crude dried powder form) were evaluated here against eggs, larvae, pupae and adults of two strains of T. castaneum i. e. FSS2, susceptible and CTC12 resistant to malathion respectively. The five different plant species were (1) Annona squamosa (A. s) Linn., (2) Aphanomixis polystacha (A. p.) Wall., (3) Polygonum hydropiper (P. h.) Linn., (4) Vitex negundo (V. n.) Linn. and (5) Sapindus mukorosis (S. m.) Gaertn. These plants have been identified and described by Indian scientists to have insecticidal properties (Anon. 1948). The plants were chosen for study in the present experiments because their activity on T. castaneum is unknown and they are readily available in tropical and sub-tropical countries.

The dried seed powder of A. squamosa has been tested against Callosobruchus chinensis as a protectant of mung seed (Pandey & Verma, 1977). The dried and powdered leaves of five plant namely, Nicotiana tabacum, Vitex negundo, Polygonum serralatum, Azadirachta indica and Leucas aspera have been used as protectant of stored wheat against the attack of Sitophilus oryzae (Kabir et al. 1984). The dried seed powder of A. squamosa and A. reticulata have long been used against head and body lice throughout many tropical countries (Harper et al. 1947).

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The extract of the seed powder of A. squamosa have been examined for contact and stomach toxicity and ovicidal properties in a variety of insects e.g. contact toxicity against Aphis fabae, Macrosiphoniclla samborni etc; stomach poison against Plutella maculipennis larvae, Diatarxia oleracea larvae etc and ovicidal activities against P. maculipennis, Ephestia kuhniella (Harper et al. 1947).

The greenish mucilagenous juice of Polygonum hydropiper has been used to kill mosquito larvae (Chopra et al. 1948). The leaves of Vitex negundo have been reported to have insecticidal properties and seeds of A. polystacha and seed pericarp of S. mukorosis have been found to be toxic against insect and fish respectively (Anon, 1948). Chawal et al.(1992) reported that the $CHCl_3$ extract of the defatted seeds of V. negundo exhibited anti-inflammatory activity and yielded four triterpenoids. Pericarps of Sapindus mukorosis have been used as a folk medicine as well as a source of natural surfactant (Wong et al. 1991). Giganenin and 4-deoxygiganteus (Annonaceae) which were active in the brine shrimp lethality test and also significantly cytotoxic to human tumor cells (Fang et al. 1992).

MATERIALS AND METHODS

Seeds of A. squamosa and A. polystacha; twigs of P. hydropiper; leaves of V. negundo and seed pericarp of S. mukorosis were dried at 30^{0}Cin an oven for 12 hours and then grounded in an electric blender and sieved through a 250 micrometer aperture sieve. Five different doses (1.0, 1.5, 2.0, 2.5, 3.0%) in a food medium (whole mealflour and dry yeast 19:1) were prepared (w/w) for each plant material. Only food medium (5g) was used for the control. The two strains of T. castaneum were collected from the stock culture of toxicology laboratories of this University. All plant materials were collected from Bangladesh after drying under sunshine at 30^{0}C . The adults insects were reared in whole mealflour and dry yeast (19:1) for collecting eggs.

One experiment was conducted on each individual plant material to assess the mortality of eggs, larvae and pupae of the FSS2 and CTC12 strains of T. castaneum individually. This experiment was conducted initially with fresh eggs and three sets of data such as egg, larval and pupal mortality were extracted from the single experiment because five different plant materials were treated with five different doses for each plant material and there was four replications for each dose on the two strains of T. castaneum.

Mortality of the eggs of FSS2 and CTC12 strains of T. castaneum

Ten fresh eggs (24 hours old) of both FSS2 and CTC12 strains were taken for each replication and were placed with treated and untreated medium individually in flat bottom glass tubes (75x19 mm). The mouth of the tubes were then closed by cotton wool. These glass tubes were then kept in an incubator at 30^{0}C, 70% relative humidity and total darkness. The number of hatched and unhatched eggs were counted upto 7 days by sieving the treated

and untreated medium every 2 days after treatment. At every observation any 1st instar larvae from each treatment were transferred into individual glass tubes (50x10 mm) for the second set of the experiment. When the eggs were examined under the microscope, it was found that the colour of unhatched eggs had changed from shine white to grey or yellow. Unhatched eggs and the eggs which changed their colour were considered as dead eggs. The number of hatched eggs were determined by counting the number of larvae and empty egg shells. The percentage mortality of eggs were corrected by Abbott's formula (Abbott, 1925) and then subjected to probit analysis (Busvine, 1971).

Mortality of the larvae of FSS2 and CTC12 strains of T. castaneum

First instar larvae of both strains resulting from the above egg mortality experiment. Larvae were placed individually in flat bottom glass tubes (50x10 mm) with freshly treated and untreated food medium (5g) and the mouths of the tubes were closed by cotton wool and kept as before. Every three days treated and untreated food medium were changed with fresh treated and untreated medium to avopid conditioning. The number of pupae were counted by seiving the food medium through a 250 micrometer apture seive after 20 to 25 days from hatching. The total number of dead larvae i.e. 1st instar to six instar were determined by substracting the number of pupae formed from the number of the 1st instar larvae used.

Mortality of the pupae of FSS2 and CTC12 strains of T. castaneum

All the pupae surviving from the larval mortality experiment were transferred individually to fresh treated and untreated food medium in closed flat bottom glass tubes (50x10 mm) and kept as before. Every three days the food medium was changed both treated and untreated until adult emergence. The number of newly emerged adults were counted by sieveing the food medium through a 250 micrometer aperture sieve. The number of dead pupae was determined by substracting the number of adults which emerged from the number of pupae used in each replication of five different doses for each plant material.

RESULTS AND DISCUSSIONS

Mortality of the eggs of FSS2 and CTC12 strains of T. castaneum

The mortality of eggs of both the strains of T. castaneum when treated by five different plant materials in crude powder form are shown in Figures 1a-e. The LD_{50} values are compared in figure 1f. The LD_{50} values, 95% confidence limits for LD_{50}'s chi^2 and resistance ratios for CTC12 strain with five different plant materials are shown in Table 1.

Annona squamosa seed powder was found to be more toxic than the other four plant materials on eggs of FSS2 and Vitex negundo was toxic for the mortality of eggs of CTC12 strain. The chi^2 values did not show any significant heterogeneity.

Mortality of the larvae of FSS2 and CTC12 strains of T. castaneum

The probit mortality of the larvae as a whole i.e. from the 1st instar to six instar of the two strains of T. castaneum are shown in Figures 2a-e and the LD_{50} values are compared in figure 2f. The LD_{50} values for the larvae, 95% confidence limits for LD_{50}'s, chi^2 values and resistance ratios are shown in Table 1.

A. squamosa seed powder was found to be more toxic than the other four plant materials for the larvae of FSS2 strain. Polygonum hydropiper twig powder was found to be the most toxic to CTC12 larvae. The chi^2 values with 3 degrees of freedom did not show any significant heterogeneity for either of the strains.

Mortality of the pupae of FSS2 and CTC12 strains of T. castaneum

The probit mortality of the pupae of FSS2 and CTC12 strains are shown in figures 3a-e and the LD_{50} values are compared in figure 3f. The LD_{50} values for the pupae with five different plant materials, 95% confidence limits for LD_{50}'s, resistance ratios and chi^2 values are shown in Table 1.

A. squamosa seed powder and P. hydropiper twig powder was found to be more toxic than the other four plant materials for the mortality of the pupae of FSS2 and CTC12 strains respectively. The chi^2 values with 3 degrees of freedom did not show any significant heterogeneity for either of the strains of T. castaneum.

The petroleum ether insoluble extract from A. reticulata seed has shown some effect against the eggs of Plutella maculipennis at the highest concentration (1.6 and 0.8% w/v) (Harper et al. 1947). Crosby (1971) reported that Annona extractives had little or no ovicidal activity. A. squamosa seed powder when mixed with mung bean (Vigna radiata L.) at the rate of 0.5 to 2.0 parts per 100 parts of seeds protected the beans against Callosobruchus maculatus infestation for 100 days (Pandey & Verma, 1977). All these previous results are more or less similar with the results of the present study. Tobacco (Nicotiana tabacum L.) leaf powder significantly affected egg development. 14% of the fertile eggs were found dead 30 days after infestation by Caryedon serratus (Delobel & Malonga, 1987). Kawazu et al. (1989) reported that a new compound from A. squamosa seed powder i.e. neoannonin had ovicidal properties against the eggs of Drosophila melanogaster. Rajapakse (1990) reported that the peel of Citrus crematofolia significantly reduced the percent of egg hatch at 0.20g/50 seeds.

The active compounds such as drimane, warburganal, muzigadial, ugandensidial and polygodial were isolated from the leaves, seeds of P. hydropiper (Jansen and Groot, 1991). Warburganal and muzigadial inhibited the feeding of the larvae of the two species of African armyworm, the monophagus Spodoptera exempta and the polyphagus S. littoralis at a concentration of 0.1 ppm.

Polygodial and ugandensidial were also antifeedants for these insects but less active. The drimane was active against S.frugiperda, Heliothis armigera and H. virescens. Polygodial was active against diamond moth larvae down to 0.1% and it inhibited food intake by fifth instar larvae of Pieris brassicae at a concentration of 200 ppm (Jansen and Groot, 1991). Callus and suspension cultures of P. hydropiper accumulated the insect antifeedant compound i.e. polygodial (Banthorpe et al. 1989).

Table 1. The LD_{50}'s, 95% confidence limits for LD_{50} values, chi^2 with 3 degrees of freedom and resistance ratio for the mortality of 3 various stages of the two strains of T. castaneum treated with five different plant materials.

Plant	Stages of insect	Strains FSS2 LD_{50}	FSS2 95% CFL	FSS2 Chi^2	CTC12 LD_{50}	CTC12 95% CFL	CTC12 Chi^2	R.R.
A.s.	Eggs	1.92	1.49-2.52	1.20	6.70*	2.63-17.87	0.29	3.50
	Larvae	1.90	1.74-2.18	1.96	3.66*	2.47-5.18	2.23	5.18
	Pupae	2.66	1.67-4.29	0.61	4.10*	2.55-6.37	0.68	1.54
A.p.	Eggs	2.50	1.96-3.22	2.15	4.80*	2.59-8.83	0.21	1.92
	Larvae	3.40*	2.24-5.06	0.14	5.57*	2.70-10.33	0.31	1.64
	Pupae	2.70	2.08-3.50	1.46	7.65*	2.08-26.39	0.31	2.83
P.h.	Eggs	3.10*	2.26-4.13	0.61	6.50*	2.74-15.00	0.45	2.09
	Larvae	3.80*	2.59-3.97	0.41	3.27*	2.41-4.32	0.08	0.86
	Pupae	3.28*	2.37-4.47	0.62	3.68*	2.39-5.79	0.50	1.12
V.n.	Eggs	3.81*	2.37-5.83	0.71	4.40*	2.68-11.52	0.14	1.15
	Larvae	3.71*	2.48-4.99	0.59	5.80*	2.52-13.01	0.05	1.56
	Pupae	3.23*	2.26-4.66	0.27	3.94*	2.62-5.28	2.03	1.22
S.m.	Eggs	4.65*	2.79-6.41	4.21	6.15*	2.97-11.52	0.27	1.32
	Larvae	2.55	2.18-3.14	5.10	5.23*	2.84-8.38	0.76	2.05
	Pupae	2.82	2.26-3.52	4.39	7.11*	2.50-8.52	1.55	2.52

A.s.= A. squamosa, A.p.= Aphanomixis polystacha, P.h.= Polygonum hydropiper, V.n.= Vitex negundo, S.m.= Sapindus mukorosis, R.R.= Resistance ratio (LD_{50} for resistance strain/ LD_{50} for susceptible strain), * = LD_{50}(%) extrapolated, CFL= Confidence limits.

A. reticulata seed extract showed toxicity to Plutella maculipennis larvae at higher concentration. The leaves of chinaberry caused mortality in the larval stages of corn earmworm, Heliothis zea and fall armyworm, Spodoptera frugiperda when it was incorporated into a meridic diet or applied to corn seedling grown in green house (McMillan et al. 1969). The seed extract of A. squamosa and Azadirachta indica have gustatory activity against the larvae of Sitophilus oryzae and T. castaneum (Qadri, 1973). Neem (Azadirachta indica) seed and leaf extract have produced 33% larval mortality of T. castaneum at 8.0% treatment (Pereira & Wohlgemuth, 1982). From this result it can be said that the seed and leaves extract of neem is less toxic than A. squamosa seed powder on the larval mortality of T.

castaneum. The neem (A. indica) seed extract incorporated into an artifical diet at 0.02, 0.2 and 2.0% (w/w) has induced mortality in all larval stages of Trichoplusia ni and Spodoptera exiuga (Prabhakar et al. 1986). Tobacco leaf powder produced 30 to 56% mortality of T. confusum larvae at $10x10^3$ and $5x10^3$ ppm after 20 days of the treatments (Khalequzzaman et al. 1988). Neoannonin from A. squamosa seed oil fraction had larvicidal activity at 125 to 140ug/2g of diet against Drosophila melanogaster (Kawazu et al. 1989). Neoannonin was a pure compound, therefore its toxicity was more than seed powder of A. squamosa in crude formed on the eggs mortality of different insects.

The flour of Lathyrus sativus L. produced a significant reduction in pupal and adult emergence of T. anaphe (Khan & Hasan, 1988). Powder of Piper nigrum significantly reduced the oviposition and adult emergence in Callosobruchus maculatus (Rajapakes, 1990). Both peppers (ground black and red) reduced the adult emergence of Callosobruchus chinensis L. at high concentration (1200 ppm) (Morallo-Rejesus et al. 1990). Nicotine reduced the survival and pupal weight and prolonged the development of Heliothis virescens F. (Gunasena et al. 1990).

None of the above described plant materials in crude powder form were able to kill any adult beetles of FSS2 and CTC12 strains of T. castaneum. From this result it can be said that the crude plant materials were unable to penetrate into the cuticle of the beetle or unable to produce a toxic effect on the exocuticle of the beetle which is harder than other stages of the beetle i.e. egg, larvae and pupae. The hardness of the cuticle of the beetle is due to the presence of a horney substance called selerotin in the exocuticle. El-Nahal et al. (1989) reported that no toxic effect could be found in the adults of Rhizopertha dominica and T. confusum when treated with the essential oil of Acorus calamus L.

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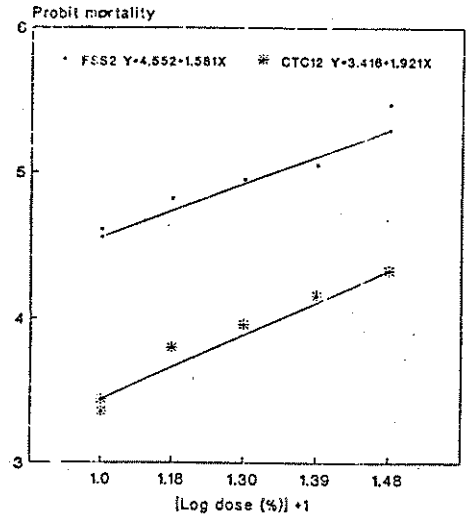

Fig 1.a Probit mortality of eggs of two strains (FSS2 and CTC12) of T. castaneum by A.squamosa seed powder.

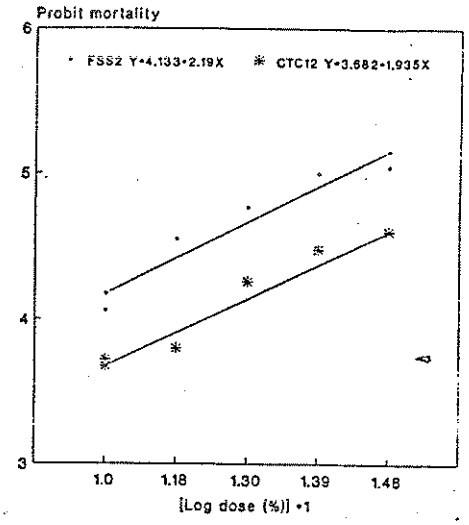

Fig 1.b Probit mortality of eggs of two strains (FSS2 and CTC12) of T. castaneum by A. polystacha seed powder.

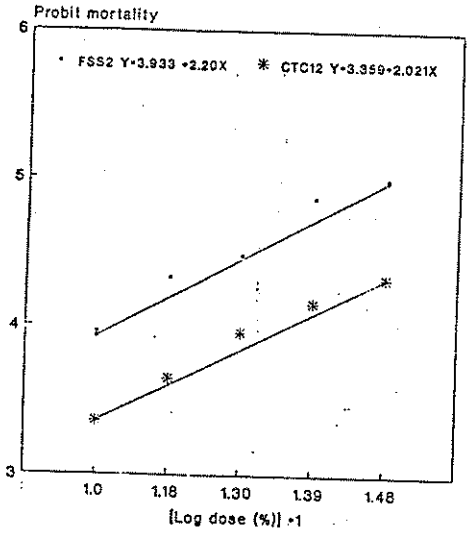

Fig 1.c. Probit mortality of eggs of two strains (FSS2 and CTC12) of T. castaneum by P.hydropiper twigs powder.

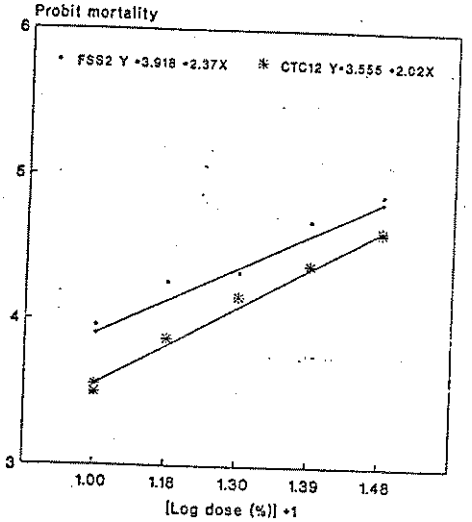

Fig 1.d. Probit mortality of eggs of two strains (FSS2 and CTC12) of T. castaneum by V. negundo leaves powder.

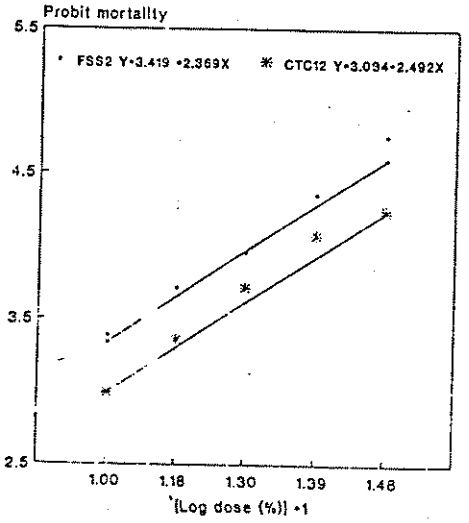

Fig 1.e. Probit mortality of eggs of two strains (FSS2 and CTC12) of T. castaneum by S. mukorosis seed powder.

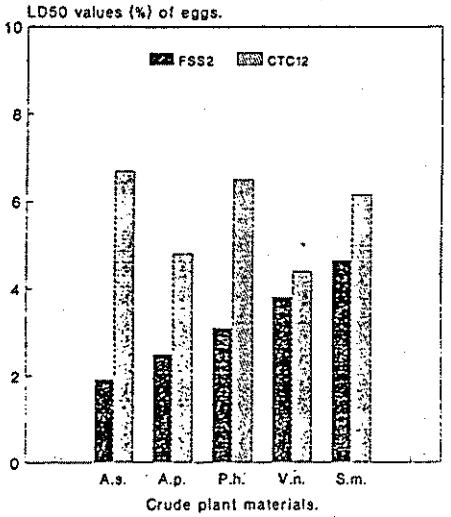

Fig 1.f. Comparing the LD50 (%) values for eggs of the FSS2 and CTC12 strains by crude plant materials.

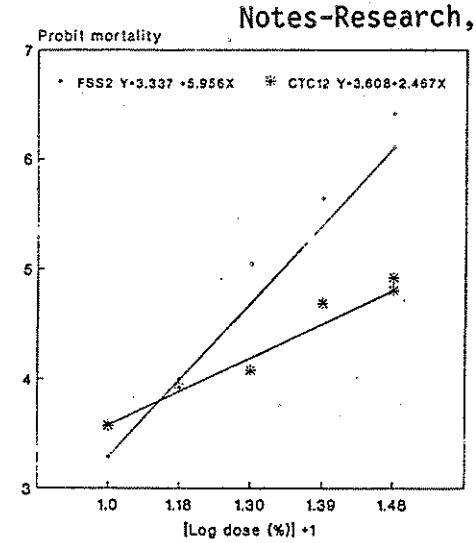

Fig. 2.a. Probit mortality of larvae of two strains (FSS2 and CTC12) of T. castaneum by A. squamosa seed powder.

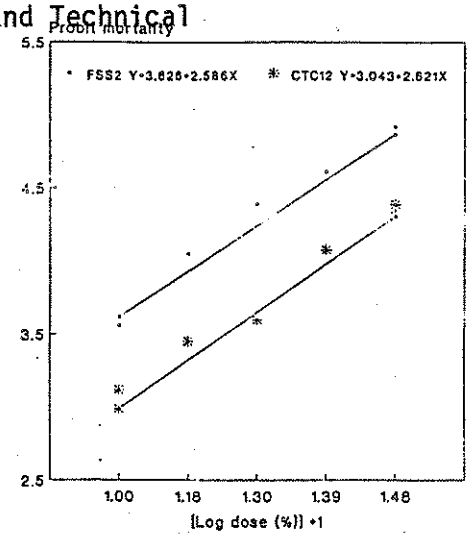

Fig. 2.b. Probit mortality of larvae of two strains (FSS2 and CTC12) of T. castaneum by A. polystacha seed powder.

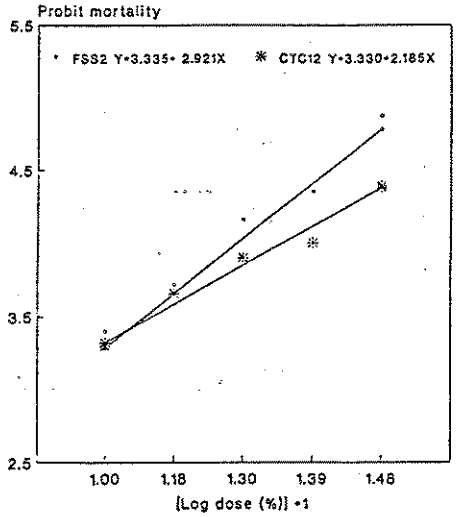

Fig. .2.c. Probit mortality of larvae of two strains (FSS2 and CTC12) of T. castaneum by V. negundo leaf powder.

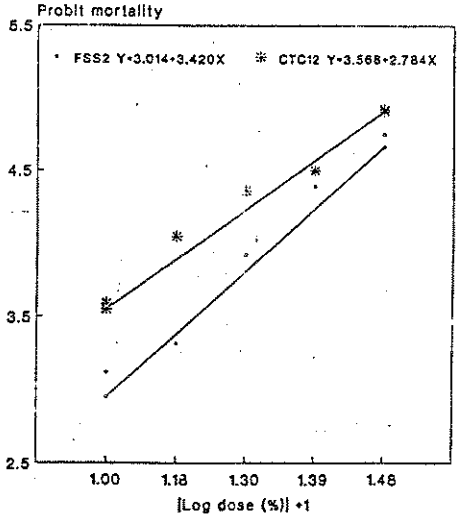

Fig. .2.d. Probit mortality of larvae of two strains (FSS2 and CTC12) of T. castaneum by P. hydropiper twig powder.

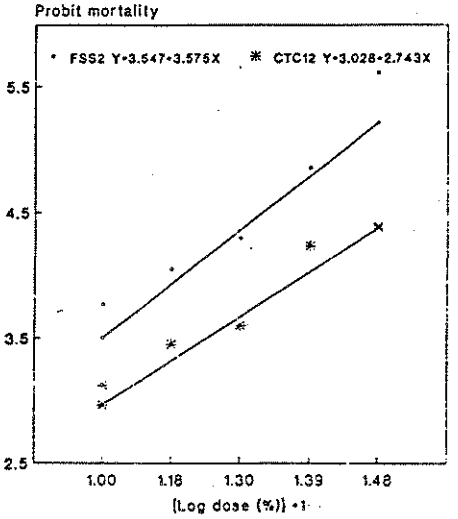

Fig. .2.e. Probit mortality of larvae of two strains (FSS2 and CTC12) of T. castaneum by S. mukorosis seed powder.

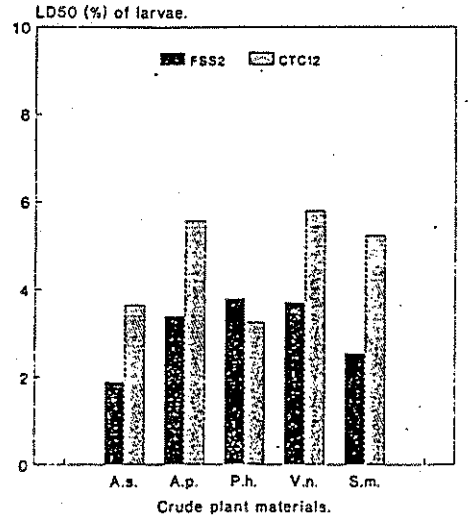

Fig. 2.f. Comparing the LD50 (%) values for the larvae of the FSS2 and CTC12 strains by crude plant materials.

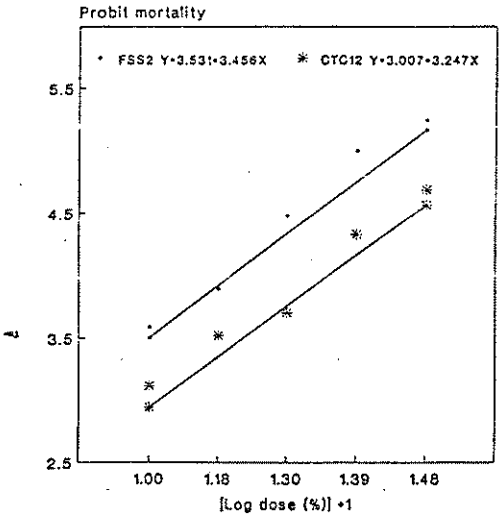

Fig .3.a. Probit mortality of pupae of two strains (FSS2 and CTC12) of T. castaneum by A.squamosa seed powder.

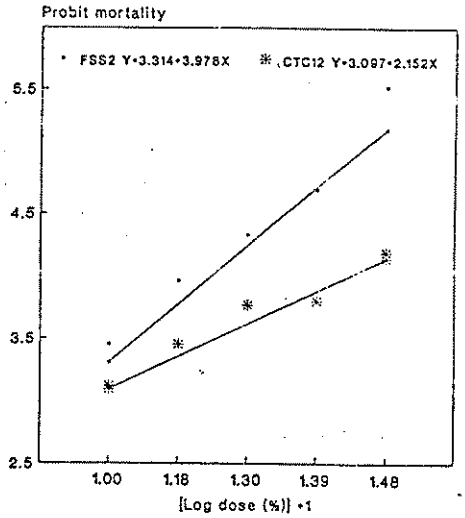

Fig 3.b. Probit mortality of pupae of two strains (FSS2 and CTC12) of T. castaneum by A. polystacha seed powder.

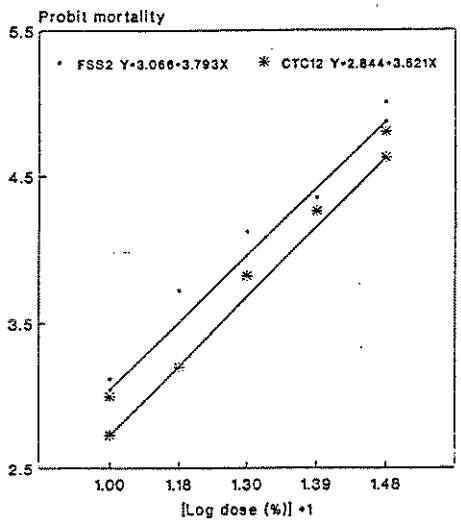

Fig 3.c. Probit mortality of pupae of two strains (FSS2 and CTC12) of T. castaneum by V. negundo leaf powder

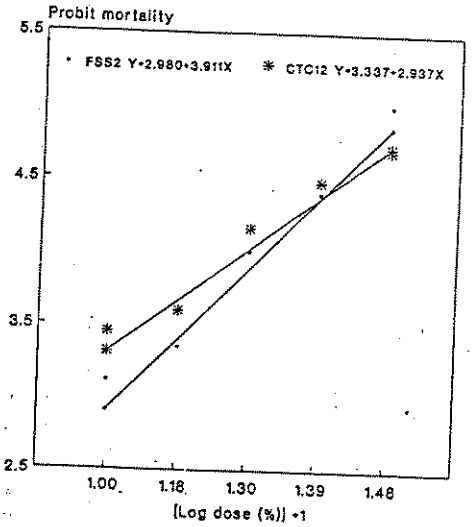

Fig. 3.d. Probit mortality of pupae of two strains (FSS2 and CTC12) of T. castaneum by P. hydropiper twig powder.

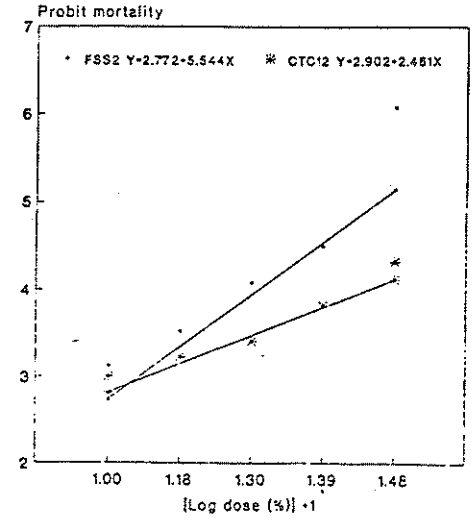

Fig. 3.e. Probit mortality of pupae of two strains (FSS2 and CTC12) of T. castaneum by S. mukorosis seed powder.

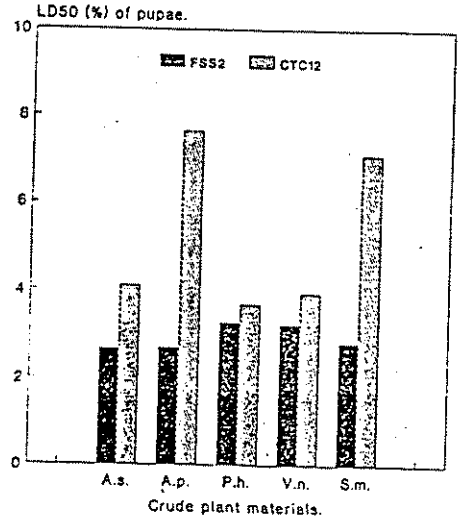

Fig. 3.f. Comparing the LD50 (%) values for the pupae of the FSS2 and CTC12 strains by crude plant materials.

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*Reproductive Potential of *Tribolium castaneum* (Herbst) (Coleoptera : Tenebrionidae) on Feed Treated with Some Plant Extracts

The rust-red flour beetle, ***Tribolium castaneum*** (Herbst) is a major pest of several stored products throughout the world. The magnitude of hazards of chemical pesticides has intensified the search for safer compounds. Safe and inexpensive methods coupled with simple application techniques are needed. Botanicals are an attractive alternative to chemical pesticides in being host-specific and biodegradable. Further, because of their low mammalian toxicity these are particularly valued for application against pests of fodders, fruits, vegetables and stored grains where safety is of prime importance.

Fecundity and fertility are two important factors having a direct bearing on insect populations. The present investigation reports the effect of leaf extracts of Bishkanthali (***Polygonum hydropiper***), Neem (***Azadirachta indica***) and Nishinda (***Vitex negundo***) on these parameters of *T. castaneum*, if any.

Adult *T. castaneum* were collected from the stock maintained at the Ecology Laboratory, Department of Zoology, Rajshahi University and were reared on wheat flour.

The leaf extracts were prepared by cold process in methanol as the solvent (Worsley 1934). Powders were prepared by pulverization of calcium carbonate in the extracts of Bishkanthali, Neem and Nishinda leaves in ratios of leaf extracts to calcium carbonate in the order 1:2.23, 1:2.23 and 1:0.75 respectively. A standard mixture of wholewheat flour with powdered yeast (19:1) was used as the experimental feed. The doses, viz. 1.0×10^4, 2.0×10^4, 3.0×10^4, 4.0×10^4, 5.0×10^4, 6.0×10^4, 7.0×10^4 and 8.0×10^4, were prepared by mixing the required amounts of the powders with the food medium.

Neonate *T. castaneum* larvae were reared on treated food up to pupation. Similar batches of control were maintained on untreated food. The resultant pupae were sexed (Halstead 1963) and kept in separate petridishes for adult eclosion. After their emergence, adults of opposite sexes were kept in individual glass vials (3.5 x 1.8 cm) containing food. For each dose 10 females were considered. Eggs were counted after sieving the contents of vials at 3-day intervals for a period of 30 days. Eggs were also observed for their fertility. The experiments were conducted at 30±0.2°C without any humidity control.

The effect of treatments was to reduce the fecundity of *T. castaneum* in the order Bishkanthali > Neem > Nishinda (Table 1). The fertility of the female beetles was also significantly reduced by treatments with the

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experimental leaf extracts in the order Nishinda > Bishkanthali > Neem (Table 2).

Few works have been conducted on the effect of plant extracts on *Tribolium* spp. (Paul *et al.* 1965, Qadri 1973, Pereira and Wohlgemuth 1982, Golob *et al.* 1982, Khanam *et al.* 1990a,b, Hossain 1990, Jahan *et al.* 1991, Khalequzzaman and Islam 1992a,b). Botanicals possess a great potential as pesticidal agents.

According to Dick (1937), *T. castaneum* belongs to the second group of the four types of egglaying observed in Coleoptera, producing eggs steadily over a long period of time. The intrinsic rate of increase of *T. castaneum* is primarily determined by oviposition early in life (Howe 1962). The results reported in the present investigation are very much promising regarding the management of this cosmopolitan pest.

Acknowledgements :

The authors are extremely grateful to the Director, BCSIR Laboratories, Rajshahi, for supplying the experimental plants and the Chairman, Department of Zoology, Rajshahi University, for providing necessary laboratory facilities. They thank Mr. Saiful Islam Faruki, a Ph.D. Fellow, Institute of Biological Sciences, Rajshahi University for his help.

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Table-1

Fecundity of *T. castaneum* females reared on treated food medium

Doses (ppm)	Bishkanthali		Neem		Nishinda	
	Mean ± S.D.	Range	Mean ± S.D.	Range	Mean ± S.D.	Range
O(Control)	61.80 ± 7.71	54–77	74.10 ± 19.20	37–104	65.00 ± 9.62	49–81
1.0×10^4	58.00 ± 11.30	49–70	60.40 ± 16.79	35– 80	47.90 ± 11.64	30–71
2.0×10^4	54.90 ± 6.08	47–67	56.40 ± 17.28	26– 76	47.50 ± 4.60	42–55
3.0×10^4	54.20 ± 5.85	42–61	52.20 ± 26.47	13– 96	46.90 ± 7.52	39–59
4.0×10^4	53.60 ± 5.54	45–61	51.20 ± 9.25	39– 67	41.70 ± 6.13	32–48
5.0×10^4	51.80 ± 10.62	33–64	47.10 ± 9.13	32– 61	36.90 ± 7.70	24–48
6.0×10^4	50.10 ± 11.96	33–73	43.70 ± 18.41	16– 75	34.90 ± 5.70	29–45
7.0×10^4	46.00 ± 7.92	34–59	38.50 ± 16.44	26– 72	33.50 ± 5.99	25–41
8.0×10^4	44.70 ± 7.12	32–56	36.70 ± 12.81	21– 51	25.70 ± 2.67	22–29

Table–2

Fertility (%) of *T. castaneum* females resulting from treated food

Doses (ppm)	Bishkanthali			Neem			Nishinda		
	Mean±S.D.	Range	d-values	Mean±S.D.	Range	d-values	Mean±S.D.	Range	d-values
0(control)	81.82±6.50	75.31-88.32	-	78.40±6.23	72.17-86.63	-	86.46±6.87	79.59-93.33	-
1.0×10^4	68.47±5.44	63.02-68.81	4.62	77.48±6.16	71.33-83.63	0.36	73.48±5.84	67.64-79.31	4.70
2.0×10^4	63.75±5.06	58.68-68.81	5.84	74.46±5.92	68.54-80.37	1.44	64.21±5.10	59.10-69.31	7.18
3.0×10^4	59.41±4.72	54.68-64.13	6.93	73.15±5.81	67.37-73.96	1.86	61.83±4.91	56.91-66.74	7.70
4.0×10^4	57.84±4.60	53.24-62.43	7.29	72.26±5.74	66.51-78.00	2.13	56.35±4.48	51.87-60.82	8.50
5.0×10^4	56.16±4.46	51.68-60.62	7.69	69.21±5.50	63.71-74.70	2.99	54.47±4.33	50.14-58.79	8.42
6.0×10^4	52.69±4.19	48.50-56.87	8.27	64.03±5.09	58.94-69.11	4.59	50.14±3.98	46.15-54.12	8.98
7.0×10^4	47.82±3.80	44.02-51.61	8.99	63.63±5.06	58.57-68.68	4.21	48.05±3.82	44.23-51.86	9.16
8.0×10^4	44.96±3.57	41.38-48.53	9.43	53.95±4.29	49.66-58.23	6.48	43.57±3.46	40.10-47.03	8.75

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*EFFECTIVENESS OF CAFFEINE AND CASTOR OIL AS REPELLENT AGAINST *TRIBOLIUM CASTANEUM*

ABSTRACT

In a food preference chamber, the effectiveness of caffeine and castor oil as repellents against *Tribolium castaneum* was studied. Both caffeine and castor oil were found to be repellent to adults and larvae of *T. castaneum*. Castor oil was more effective than caffeine. There was a significant difference ($P<0.05$) in response between sexes of adults - males being more responsive than females to castor oil. Both early and late larval instars were also more responsive than other instars.

INTRODUCTION

Tribolium castaneum Herbst is a major pest of stored products and is cosmopolitan in distribution (Good, 1933 Sokoloff, 1972, 1974). Both adults and larvae are able to exploit a wide variety of stored commodities (Ziegler, 1977).

In many countries locally available plant materials are widely used as protectants of stored products against insect pests. The effectiveness of many plant derivatives for use against grain pests has been reviewed by Jacobson (1958,1975,1990). The insect repellent and antifeedant properties of neem (*Azadirachta indica*), tobacco (*Nicotiana tabaccum*), Nishinda (*Vitex negundo*), Bishkatali (*Polygonum serrulatum*), Dhandakalas (*Leucas aspera*), turmeric (*Curcuma longa*) have been reported against stored product pests viz, *Trogoderma granarium* (Jotwani and Sircar,1965), *Rhyzopertha dominica* (Pereire and Wohlgemuth, 1982), *Sitophilus oryzae* (Ahmed *et al.*, 1980; Kabir *et al.* 1984; Mia *et al.* 1985), *Tribolium castaneum* (Jilani and Malik, 1973; Qadri, 1973; Jilani *et al.*, 1988; Parveen and Mondal, 1992), *Tribolium confusum* (Mondal and Begum, 1991) and *Sitotroga cerealella* (Abraham *et al*; 1973). Moreover different plant oils viz., soybean oil, peanut oil, cottonseed oil, maize oil, rice bran oil, groundnut oil and citrus oil have also been reported as protectants of stored products against insect pests (Pandey *et al.*, 1977, 1981; Shaaya and Ikan, 1980; Yadara, 1971; Su *et al.*, 1972a,b; Singh *et al.*, 1978; Schoonhoven, 1978; Qi and Burkholder, 1981; Messina and Renwick, 1983; and Jilani *et al.*, 1988).

In the previous experiment both caffeine and castor oil were found to be toxic to adults and larvae of *T. castaneum* (Mondal and Akhtar, 1992). However there is no information concerning the effectiveness of caffeine and castor oil as either repellent or attractant against stored product-pests. This led to the present work. Caffeine (1,3,7-Trimethylxanthine)-an important compound of coffee (*Coffea arabica*) and tea (*Cornellia sinensis*) is the most important purine and mutagenic agent. It is also an alkaloid and is responsible for stimulating action on central nervous system (Noller, 1958; Rakoff and Rose, 1966; Cordell, 1981). Castor oil from the seed of the castor bean plant (*Ricinus communis*) yields fat acid characterized by the high concentration of the hydroxy unsaturated acid, picinoleic acid (DePuy and Rinehart, 1975).

MATERIALS AND METHODS

The experiment was conducted in a 'choice chamber' consisting of a plastic petridish (5cm diameter) divided into two equal halves by a mark on the outer surface. Each half was loaded with approximately 1g of flour, either fresh or treated with caffeine or castor oil. Ten adults of either sex or larvae were introduced at the middle of the dish and was covered with a lid, thus providing an option for the test insects to select either the fresh medium or treated medium (Mondal, 1983). The petridish was kept in an incubator at 30°C. The number of test insects on each half of the petridish was recorded after 24 hours by sieving the flour medium. The tests were replicated five times for each treatment and conducted with both larvae and adults separately. Larvae used in the experiment were collected from a *T. castaneum* larval culture on 6th, 9th, 12th and 18th day from hatching which correspond to third, fourth, fifth and sixth instars in control respectively (Mondal, 1984). Newly hatched (first instar) and second instar larvae were not used in the experiment because of their small size. Sexes of adults were determined in the pupal stage (Halstead, 1963) and adults of both sexes aged between 10-20 days were used in the experiment. In each test fresh larvae or adults were used. Flour media treated with either caffeine at the concentrations of 250,500 and 1000ppm or castor oil at the concentrations of 100, 200 and 300ppm were used in the experiments.

RESULTS AND DISCUSSION

The results of the experiments and statistical analyses are shown in Tables 1 and 2. *T. castaneum* adults and larvae were repelled by both caffeine and castor oil. There were variable responses of adults to different concentrations of caffeine. Adults of both sexes were either attracted or showed no response to low concentrations (250 and 500ppm) of caffeine. Only males were repelled by caffeine at high concentration (1000ppm). Castor oil was found to be more repellent than caffeine. There was a significant difference ($P < 0.05$) in response between sexes of adults - males being more responsive than females. Similarly a higher proportion of third and sixth instar larvae were repelled by both caffeine and castor oil suggesting that both early and late larval instars are more responsive than other instars. No larvae of all instars were found in medium treated with castor oil at a concentration of 300ppm indicating the medium highly repellent (table 2).

The present result is similar to those of the previous workers who reported the repellent action of various plant materials against different species of stored product insect pests (Jotwani and Sircar, 1965; Abraham *et al.*, 1973; Jilani and Malik, 1973; Qadri, 1973; Ahmed *et al.*, 1980; Golob *et al.*, 1982; Kabir *et al.*, 1984; Mia *et al.*, 1985; Jilani *et al.*, 1988; Mondal and Begum, 1991). The repellent action of castor oil is also similar to the findings of Pandey *et al.*, (1977, 1981), Shaaya and Ikan(1980), Yadara (1971), Su *et al* (1972a,b), Singh *et al.* (1978), Schoonhoven (1978), Qi and Burkholder (1981), Messina and Renwick (1983), Jilani *et al.* (1988) and Parveen and Mondal (1992) who reported soybean oil, peanut oil, cottonsead oil, maize oil, rice bran oil, groundnut oil, citrus oil, turmeric oil, sweetflag oil and neem oil repellent against different stored product pests.

The repellent action of both caffeine and castor oil indicates their possible use in the control of *Tribolium* in warehouses as repellents (Dethier, 1956). Bags or containers treated with repellent caffeine or castor oil may prevent *Tribolium* adults and larvae from attacking and infesting the food.

Although the post harvest losses of food grains are commonly protected by insecticides or fumigation, such practices pose human health risks, environmental hazards and pesticide-resistant pest strains. However, these problems can be overcome if the compounds of low mammalian toxicity without environmental hazards are used. Plant derivatives that traditionally have been used as grain protectants in developing countries as repellents may serve this purpose. As repellent they may offer protection and comfort without disturbing any

Table 1. Number and percentage of *T. castaneum* adults and larvae in medium treated with caffeine

Conc. (ppm).	Life stage (adults = sex; Larvae = age in days)	Distribution of adults/larvae Total nos.	% total	X^2 (1df.)
250				
	Male	32	64	3.92*
	Female	36	72	9.68**
	6	14	28	9.68**
	9	24	48	0.08^{NS}
	12	26	52	0.08^{NS}
	16	37	74	11.52***
500	Male	34	68	6.48*
	Female	20	40	2.00^{NS}
	6	07	14	25.92***
	9	24	48	0.08^{NS}
	12	28	56	0.72^{NS}
	16	38	76	13.72***
1000	Male	14	28	9.68**
	Female	27	54	0.32^{NS}
	6	05	10	32.00***
	9	17	34	5.12*
	12	23	46	0.32^{NS}
	16	18	36	3.92*

Table 2. Number and percentage of *T. castaneum* adults and larvae in medium treated with castor oil.

100	Male	02	4	42.32*
	Female	09	18	20.48*
	6	09	18	20.48*
	9	10	20	18.00*
	12	03	6	38.72*
	16	02	4	42.32*
200	Male	02	4	42.32*
	Female	09	18	20.48*
	6	-	-	-
	9	03	6	38.72*
	12	03	6	38.72*
	18	-	-	-
300	Male	03	6	38.72*
	Female	06	12	28.88*
	6	-	-	-
	9	-	-	-
	12	-	-	-
	16	-	-	-

Five replicates per test, each replicate consisting of 10 test insects (N=50)
NS Not significant, P>0.05; *Significant, P<0.05; **Significant, P<0.01; ***Significant, P<0.001

ecosystem because repellents are considered safe as they minimise pesticide uses and environmental hazards (Jilani *et al.*, 1988). In recent years there has been a resurgence of world-wide interest in natural plant materials as agents for insect pest control (Jacobson, 1990). Botanicals possess low mammalian toxicity without environmental hazards. Thus, the use of both caffeine and castor oil as repellent against *Tribolium* may prove to be important from the integrated pest managment point of view.

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*INTRA AND INTERSPECIFIC RESPONSES OF *TRIBOLIUM CASTANEUM* AND *TRIBOLIUM CONFUSUM* TO CONDITIONED MEDIUM

ABSTRACT

Both intra and interspecific responses of adults and larvae to conditioned medium were studied in *Tribolium castaneum* Herbst and *Tribolium confusum* Duval. Flour conditioned by both *T. castaneum* and *T. confusum* were attractant to adults of both species, but repellent to *T. confusum* larvae. *T. castaneum* larvae were attracted to flour conditioned by *T. confusum* whilst repelled by flour conditioned by the conspecies. *T. confusum* was more responsive than *T. castaneum*, but there was no significant difference ($P > 0.05$) in response between sexes in both species.

INTRODUCTION

A medium in which *Tribolium* beetles have lived for some period is called "conditioned" (Park, 1937; Sokoloff, 1974). A few beetles are enough to condition the flour medium giving a persistent and disagreeable odour, turning the flour pinkish (Chittenden, 1896; Engelhardt *et al.*, 1965), adversely affecting the viscous and elastic properties of the flour and create a disgusting taste (Payne, 1925). Conditioning is one of the major stimuli for dispersal and aggregation by *Tribolium* (Loconti and Roth, 1953) and it depends on the number and sex of insects, and the duration of occupation (Ghent, 1963; Mondal, 1983, 1985). Conditioning of the medium involves the depletion of the nutritive value of the medium; accumulation of exuviae, dead insects and similar debris; and most markedly, accumulation of the quinones (Roth, 1943) and pheromones (Suzuki and Sugawara, 1979) given off by the adults *Tribolium* and taken up by the medium (Ghent, 1963; Sokoloff, 1972).

Flour conditioned by adult conspecifics was repellent to *T. castaneum* adults and larvae, but attractive to *T. confusum* adults due to the production of quinones (Ghent, 1963; Ogden, 1969; Mondal, 1983, 1985). Later, adults of both sexes of *T. confusum* (Ryan and O'Ceallachain, 1976; O'Callaghan, 1977; O'Ceallachain and Ryan, 1977; Hughes, 1982), *T. castaneum* (Suzuki and Sugawara, 1979) and *T. brevicornis* (Faustini *et al.*, 1982a, b) were reported to be attracted to flour conditioned by male conspecifics which was explained as being due to the production of an aggregation pheromone (Suzuki and Sugawara, 1979; Suzuki, 1980).

All the previous works were on the intraspecific responses to conditioned medium. However, there is no information concerning the interspecific responses of *Tribolium* species to naturally conditioned medium. This led to the present experiment.

MATERIALS AND METHODS

The experiment was conducted in a 'Choice Chamber' consisting of a plastic petridish (9cm diameter). A filter paper was placed on the floor of the dish and the petridish was divided into two equal halves by a mark on the filter paper. Approximately 1g of fresh flour was placed at the middle of one half of dish (control) and 1g of conditioned flour was placed at the middle of the other half. Twenty adults of either sex or larvae were introduced at the middle of the dish and was left uncovered, thus providing an option for the test insects to

select either the fresh flour or conditioned flour (Mondal, 1983). The petridish was kept in an incubator at 30°C. The number of insects invaded the conditioned flour was recorded after one hour.

The tests were replicated five times for each treatment and conducted with adults of both sexes and larvae separately. Flour media inhabited by *T. castaneum* and *T. confusum* populations separately for approximately nine months were used as conditioned media. Larvae aged 16 days which correspond the sixth intar (Mondal, 1984) and adults of both sexes aged between 10-20 days were used as test insects in the experiment. Sexes of adults were determined in the pupal stage (Halstead, 1963). In each test fresh adults or larvae were used. The conditioned media were obtained from the Department of Agricultural and Environmental Science, University of Newcastle upon Tyne, United Kingdom.

RESULTS AND DISCUSSION

The results of the experiments and statistical analyses are shown in table 1. The results were tested using chi square based on an expected distribution of 50:50. The media conditioned by both *T. castaneum* and *T. confusum* were attractant to adults of both species, but were repellent to *T. confusum* larvae. *T. castaneum* larvae showed variable responses. They were attracted to flour conditioned by *T. confusum* whilst repelled by flour conditioned by the conspecies. *T. confusum* were more responsive to conditioned media than *T. castaneum*. There was no significant difference ($P > 0.05$) in response between sexes of both species.

The attraction of medium conditioned by *T. castaneum* and *T. confusum* beetles to adults of both species is similar to the findings of Ryan and O'Ceallachain (1976), O'Ceallachain and Ryan (1977), O'Callaghan (1977), Suzuki and Sugawara (1979), Faustini *et al.* (1982a, b), Hughes (1982) and Mondal (1985) who reported that medium conditioned by male conspecifics was attractive to the adults of both sexes of *T. castaneum*, *T. confusum*, and *T. brevicornis*. It is possible that the adult attraction to these conditioned media might be due to the presence of an aggregation pheromone (4,8-Dimethyldecanal) produced by males (Suzuki and Sugawara, 1979; Suzuki, 1980). The present results also support the findings of Ghent (1963) and Ogden (1969) with *T. confusum*, but contrast with *T. castaneum* who reported flour conditioned by conspecific adults was repellent to *T. castaneum* adults, whilst attractive to *T. confusum* adults.

Larvae of *T. confusum* were repelled by the flour conditioned by beetles of both species. *T. castaneum* larvae also showed similar response to medium conditioned by conspecies only. This repellent result is similar to those of Mondal (1983, 1985) who reported larvae of *T. castaneum* were repelled by medium conditioned by adult conspecifics at high densities or during long period. This repellent effect might be due to the presence of quinones and/or accumulation of exuviae, dead beetles and similar debris as explained by Mondal (1983, 1985).

In the present experiments the medium was conditioned for long period (9 months) by the populations (adults, larvae and pupae) of *T. castaneum* and *T. confusum* separately in an incubator under same conditions. Although the exact numbers of conditioning beetles were not known, but densities of the beetles in both media were extremely above the realistic upper limit (Ogden, 1969). Both media were heavily conditioned turning into pinkish colour which indicated the presence of quinones produced by both sexes of adults (Mondal, 1992). According to the reports of previous workers the conditioned media used in the present experiments were supposed to be repellent to adults and larvae of both species due to the presence of quinones, but the result was quite different. They were attractant. However, this attraction does not seem to be due to an aggregation pheromone produced by the male adults because it is produced only at low densities of the beetles or during the short period of conditioning. It is possible that both quinones and pheromones are secreted at continuous rates in all conditions. However, the pheromone is volatile and, therefore, whilst present early on, does not accumulate. The quinone, on the other hand, accumulates and eventually masks the pheromone. When the

flour was conditioned for nine months the quinones would be dominant over the pheromone. Quinones are pheromone parsimony (Blum, 1970). They act as epideictic pheromones at high population densities by dissolving aggregation pheromone globules and thus, under stressful conditions of overcrowding and lack of sufficient food resources, the pheromone is inhibited (Faustini and Burkholder, 1987).

The attraction of conditioned media in the present experiment may be due to the presence of other semiochemical secreted by adults or larvae in addition to the previously reported quinones or pheromones which is not known. It needs further investigation. However, the present results indicate that conditioning of medium may be due to the presence of quinones, pheromones or other unknown semiochemical(s).

Table 1. Number and percentage of *T. castaneum* and *T. confusum* adults and larvae in fresh medium (control) and conditioned medium

Conditioning species	Responding species	Life stage	Distribution of beetles Nos. in fresh	Nos. in conditioned	% total in conditioned	X^2 (1df)
T. castaneum	*T. castaneum*	Male	33	67	67.0	11.56*
		Female	33	67	67.0	11.56*
		Larvae	56	44	44.0	1.44^{NS}
	T. confusum	Male	15	85	85.0	49.0*
		Female	03	97	97.0	88.36*
		Larvae	71	29	29.0	17.64*
T. confusum	*T. confusum*	Male	07	93	93.0	73.96*
		Female	03	97	97.0	88.36*
		Larvae	70	30	30.0	16.00*
	T. castaneum	Male	23	77	77.0	29.16*
		Female	21	79	79.0	33.64*
		Larvae	29	71	71.0	17.64*

Five replicates per test, each replicate consisting of 20 insects (n=100)
^{NS}Not significant, $P>0.05$; *Significant, $P<0.001$

CONCLUSION

Although in the present experiment the exact chemical rendering the flour medium conditioned is unknown, but it is important that it can be used in the control of *Tribolium* populations as either attractant (Dethier *et al.*, 1960) or repellent (Dethier, 1956; Painter, 1967). Both attraction and repulsion are based on olfactory causes, since the beetles used in the experiments responded whilst not in contact with conditioned medium. Bags of

grains or containers treated with this chemical may prevent *Tribolium* as repellent from attacking and infesting the food (Mondal and Port, 1984a; Mondal, 1989). Alternatively, as attractant it may also be used to detect and lure populations of *Tribolium* into traps where they can be easily killed or destroyed by suitable insecticides, pathogens or mechanical method (Mondal and Port, 1984b).

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THE SIMULATION OF SIRE GENETIC EVALUATION USING TRIBOLIUM CASTANEUM FOR THE COMPARISON OF TWO STATISTICAL METHODS

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ABSTRACT

The simulation of sire genetic evaluation by using Tribolium castaneum for the comparison of two statistical methods: Henderson' s method 3 and REML for the estimation of variance and covariance components, and also the comparison of two selection methods. The same data set of pupal length and pupal width in two generations was analysed by two methods. Results showed that heritabilities of two traits estimated by Henderson's method 3 were lower than that estimated by REML and did not remain stable in two generations. The ranking of each family average of breeding value showed that the usual method may be used for sire evaluation when the heritabilities of selected traits are middle in heigh.

INTRODUCTION

Selection for improved performance of an economic trait using a selection index. The value of selection by indices is dependent on both the accuracy(Lin et al, 1979) and the variance of parameters(Hill,1974).

Henderson's method 3 is useful for all general mixed models, unbiased and translation invariant, not unique. It is more difficult than method 1 or 2 computationally and is more accurate than method 1 or 2. The procedure of disadvantage: for most models there are more reductions that can be computed than are necessary to estimate the variances. There are no rules for selecting those reductions that will give variance component estimates with the lowest sampling variances.

REML(Restricted Maximum Likelihood) has general characteristics: translation invariant,estimates required to be within the parameter space, must

be solved iteratively, requires normality. REML can be derived from the MIVQUE algorithm or by maximum likelihood.

For experimental verification of theoretical aspects of quantitative genetics, the experimenter is interested in using an organism which has a shorter generation interval and which is more economical to maintain, Tribolium castaneum offers many advantages for this work.

The simulation of sire genetic evaluation by using T. castaneum for the comparison of two statistical methods: Henderson's method 3 and REML for estimation of variance and covariance components and also the comparison of two selection methods.

MATERIALS AND METHODS

1. Foundation population: WT Tribolium castaneum in Lab of Dept. of Animal Genetics and Breeding, Beijing Agricultural University.

2. Medium: 95% whole wheat flour and 5% yeast.

3. Incubator: The beetles were maintained in an incubator at 32 ℃ and 60% relative humidity.

4. Genration zero: 30 single-pair random matings for 5 days before 24-hour egg collection came from the foundation population. They were used as a selected population; Four 5-pair random mating groups were used as a control population.

5. Selection experiment extended over two generations and consisted of four replication with 215 progenies per generation per replication.

6. Two methods:

(1)Henderson's method 3

$$I = \sum b_i \times \sum p_i$$

(2)REML and BLUP

7. Models:

(1)The sire model used for this analysis was:

$$y_{ijklm} = \mu_m + H_{im} + Sex_{jm} + u_{km} + e_{ijklm}$$

where:

y_{ijklm}: *phenotypic value of trait m*

μ_m: *overall mean of trait* $m (m = 1,2)$

H_{im}: *replicate − day block effect*$(i = 1,2,3,4)$

Sex_{jm}: *sex effect*$(j = 1,2)$

u_{km}: *sire effect*$(k = 1,2,\cdots,30)$

e_{ijklm}: *random error term.*

(2)The animal model used for this analysis was the same.

where: u_{km}: individual effect

8. Ranking breeding value of the sires using the two methods.

RESULTS AND DISCUSSION

1. F tests of family, replicate−day and sex effects were significant at $p < 0.01$(Table 1). It suggested that it is necessary to eliminate the fixed effects while estimating the breeding value.

Table 1. Analysis of variance for pupal length and width of generation zero.

source of variation	degree of freedom	pupal length			pupal width		
		sums of squares	mean of squares	F	sums of squares	mean of squares	F
Family	28	105594.26	3771.224	7.145**	9980.00	356.428	9.227**
Replicate −day	3	108441.23	36147.076	71.406**	5323.66	1774.553	45.936**
sex	1	37395.148	37395.148	73.872**	1588.976	1588.976	41.133**
Error	827	418641.91	506.718	—	31947.492	38.631	—

** : significant at $p < 0.01$

2. The genetic parameters of pupal length and width were different using two method,and the genetic parameters were equabler using REML than Henderson's method 3 in the two generations.

Table 2. Genetic and phenotypic parameters estimated by two methods.

Method	Trait	Generation zero				Generation one			
		h^2	r_A	r_E	r_P	h^2	r_A	r_E	r_P
method I	pupal length	0.360				0.183			
	length × width		0.840	0.717	0.764		0.797	0.506	0.556
	pupal width	0.437				0.162			
method II	pupal length	0.5879				0.5465			
	length × width		0.2795	0.5864	0.3953		0.4077	0.5420	0.4671
	pupal width	0.6513				0.5673			

3. Sire evaluation using two methods was nearly the same for the trait which has the mid-high h^2. The best five sires in the ranking of the sire breeding value were the same using the two methods. The rest of five sires selected were 80% the same, although the ranking was not the same.

Table 3. The sire evaluation using two selection methods.

Rank	1	2	3	4	5	6	7	8	9	10
Sire number method I	14	12	11	15	22	21	20	2	4	24
Sire number method II	14	12	11	15	22	2	4	24	26	21

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The repair of genetic damage in Tribolium freemani black and T. freemani-T. castaneum black hybrids through injection of b-alanine.

INTRODUCTION

Catecholamines such as b-alanine, dopamine, N-acetyl-dopamine and N-b-alanyldopamine are intricately involved in pigment and cuticle sclerotization in T. castaneum (Kramer et al., 1987). A mutant strain of T. castaneum, T. castaneum black has been shown to recover from genetic damage when treated with b-alanine in the teneral adult stage (Kramer et al., 1984). Spray and Sokoloff, unpublished, have identified a black mutant in T. freemani. T. freemani and T. castaneum are both in the castaneum species group, and when hybridized produce abundant progeny (Nakakita et al., 1981, Brownlee and Sokoloff, 1988). Also, autosomal mutants in T. freemani have been found to have superficial resemblance to known mutants of T. castaneum (Carrillo and Sokoloff 1991). The above, along with the identification of homologous genes in T. castaneum and T. freemani (Spray and Sokoloff 1991), give support to the relative closeness of the two species.

This experiment was to determine if injection of b-alanine into T freemani black would produce the wild-type body color and also to determine if hybrids between T. castaneum and T. freemani black would produce the wild type color when injected with b-alanine. This study gives support to the idea that the species have very similar if not identical biochemical pathways leading to the production of body color and cuticle sclerotization.

MATERIALS AND METHODS

Three Tribolium stocks were used in this study. (1) A pure breeding strain of T. castaneum black. (2) A pure breeding strain of T. freemani black. (3) A cross of T. freemani black and T. castaneum black for the purpose of obtaining hybrids. The medium was prepared from approximately 5 grams of whole wheat flour containing .02 grams of Fumidil-B (Bicyclohexylammonium Fumagillin, an anti-parasitic drug). All stocks were kept in an incubator at 29 C and 70 percent r.h. To assure abundant progeny, the parental generation was transferred weekly to a new set of creamers containing a fresh medium. After a period of 3 weeks, the emerging pupae, ranging from opaque to black in eye color, were removed from the creamers. A 33 gage micro-syringe was used to inject approximately .1 microliters of a 4 molar b-alanine solution. This dosage had proven optimal in previous experimentations (Roseland et al., 1983). Each pupa was then immobilized using forceps. The needle was then inserted between the third and fourth segments

directed towards the thorax. The wounded pupae were then placed in a bed of flour and allowed to recover and proceed in their development in the incubator. After a 2 to 3 day period, the beetles were removed and examined according to pigmentation.

RESULTS AND DISCUSSION

The expression of wild-type pigmentation from the T. freemani black and the T. freemani-T. castaneum hybrids was successful. However, we were not able to recover any of the T. castaneum black that were injected. Of the 248 T. freemani black pupae injected with @ .1 microliters of 4 molar b-alanine solution, only 6 percent developed the wild-type color. Moreover, of the 50 T. freemani-T. castaneum black hybrids, 14 percent became chestnut. The other pupae did not survive the injury and/or received too much or not enough b-alanine to emerge as chestnut. Our crude instrumentation also played a part in the numbers. However, as time progressed, we became more skilled. The results are listed in Table 1.

Our project differed from Kramer et al., 1984 in that we chose to use the pupal stage for the injection of b-alanine. This was for several reasons: (1) The pupal stage allowed a broader time range within which injections could be accomplished. (2) The pupae were much easier to secure than the teneral adult stage. (3) The levels of catecholamines were the same for the wild-type and the black strains at this stage (Kramer et al., 1984).

These results, along with the fact that the two species are able to produce hybrids of mutants demonstrated to have homologous genes, lead to the idea that the species have only recently diverged and that they may have retained similar or if not identical pathways in the production of body color and cuticle sclerotization.

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Table 1. Numbers in relation to survival and pigmentation.

	Injected	Survived	Chestnut	Black
T. freemani	247	66	16	49
T. castaneum	25	0	-	-
T.c - T.f	50	30	7	23

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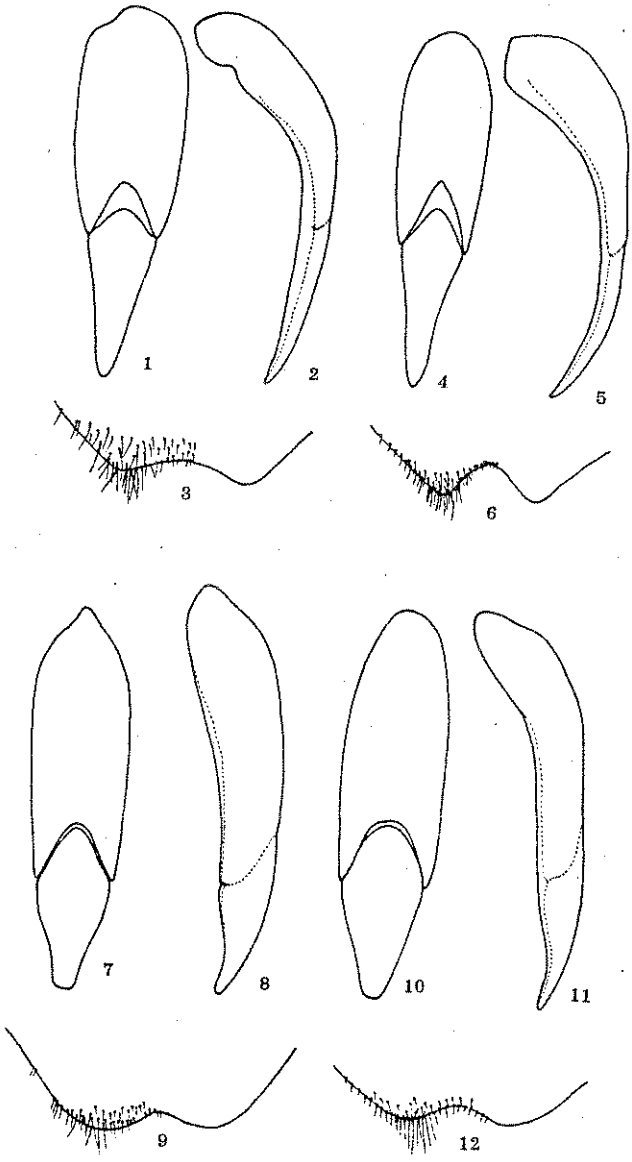
* Identification of four species of the castaneum species-group of Tribolium (Coleoptera: Tenebrionidae).

Tribolium freemani Hinton was rediscovered in 1981 in Japan from imported corn. We believe that the species of Tribolium in China previously described as T. madens actually should be T. freemani by examining intercepted specimens sent by Dr. Nakakita. The species is widely distributed in the Sinkiang Province. Besides, it was rarely found in the following provinces of China: Gansu, Ninzin, Shanxi and Yunnan. It causes some damage to several stored products such as wheat, wheat bran and wheat flour, corn and corn flour, rice, apricot stones. Several living adult and larva specimens also were collected from dry ground beetles and tortoise shells in drug stores.

Halstead (1969) gave characters to distinguish T. audax and T. madens. This paper provides comparisons of T. audax, T. madens, T. freemani and T. castaneum (Table 1). The data on T. audax and T. madens is based on Halstead's studies.

By comparing male genitalia of four species (Figs. 1-12) it is revealed that the genitalia of T. audax is much more similar to that of T. madens that to that of T. freemani or T. castaneum, and the genitalia of T. freemani is much more similar to that of T. castaneum than to that of T. audax and T. madens.

Crosses made between T. audax and T. madens produced a few infertile F1 hybrids (Halstead, 1969). Interspecific crosses between T. freemani and T. castaneum produced many infertile F1 hybrids. Crosses between T. freemani and T. madens and between T. freemani and T. audax were tried, but no F1 progeny were obtained. So the conclusion is that, in the castaneum-section, T. freemani is closer to T. castaneum than to T. madens or T. T. audax (Nakakita, 1983). The conclusion is supported morphologically by comparing the genitalia of the four species.



Figs. 1—12. Tribolium spp. 1–2 T. audax aedeagus, (1) dorsal view, (2) side view. 4–5 T. madens aedeagus, (4) dorsal view, (5) side view. 7–8 T. freemani aedeagus, (7) dorsal view, (8) side view. 10—11 T. castaneum aedeagus, (10) dorsal view, (11) side view. 3, 6, 9, 12 periphallic sternite, (3) T. audax, (6) T. madens, (9) T. freemani, (12) T. castaneum. (Fig. 1–6 from Halstead).

Table 1. Characters for distinguishing four species of castaneum-group

	T. audax	T. madens	T. freemani	T. castaneum
Body length and colouration	2.84—4.47 mm. Very dark brown with tegs and antennae lighter	3.89—5.09 mm. Very dark brown with tegs and antennae dark brown to brown	4.13—4.89 mm. Dark reddish brown	3.84—4.28 mm. Dark reddish brown
Punctures of region between eyes	Dense, medial punctures usually separated transversely by breadth or less	Less dense, separated transversely by 1—2 breadths	Dense, medial punctures usually separated transversely by breadth or less	Dense, medial punctures usually separated transversely by breadth or less
Ventral distance between the eyes	2.6—3.7 X Ventral transverse dia. of eye	1.6—2.3 X Ventral transverse dia. of eye	1.5—2.3 X Ventral transverse dia. of eye	1.00—1.25 X Ventral transverse dia. of eye
Breadth of narrowest part of eye divided by side of front	4—5 facets	4—5 facets	2—3 facets	4—5 facets
Male anterior femora	simple	With sub-basal setiferous pit	With sub-basal setiferous pit	With sub-basal setiferous pit
Male genitalia				
(a) Periphallic sternite	Apex moderately emarginate (Fig. 3)	Apex strongly emarginate (Fig. 6)	Apex more emarginate (Fig. 9)	Apex more emarginate (Fig. 12)
(b) Aedeagus	Fig. 1—2	Fig. 4—5	Fig. 7—8	Fig. 10—11

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*A succession of habitats in laboratory cultures.

As pointed out by Lezcano and Sokoloff elsewhere in this issue of TIB, overcrowding either as an incidental occurrence during the course of an experiment or deliberate, involving last instar larvae only, adults only or all stages of flour beetles, may result in drastic changes in the flour medium, leading to the loss of the culture.

The changes are associated with an increase of moisture within the culture resulting from the metabolic activities of the beetles. Moisture forms in tiny droplets on the inside surface of the vial or any glass container, and it is gradually absorbed by the flour. The flour then gradually loses its particulate nature and becomes sticky. At a certain point, mold spores are stimulated to form mycelia and as the mat the mycelia form becomes thick, it will entrap some of the larvae or adults. The survivors are driven to the surface of the medium. Starvation may force the beetles back into the sticky medium. As moisture is reduced, the sticky flour may be covered with fungal mycelia which then can serve as food for the flour beetles.

As the flour dries, it forms a plug which detaches itself from the container's walls, or it may turn to a black liquid in which the beetles drown.

Gradually the beetle population decreases, and as the plug dries further the survivors may use it as a source of food. Some larvae may move toward the surface of the plug, or to the galleries which both the larvae and adults have dug within the plug. The larvae may pupate in the tunnels and complete their development, producing more adults, but usually the population within the container declines and dies.

The changes have been observed to occur in one dram vials or in pint milk glass bottles. The essential factor is to have a dense population (for Tribolium freemani the critical density appears to be about 100 last instar larvae or 100 adults per gram).

During an experiment requiring a great deal of replication, the larvae, pupae and adults of Tribolium freemani were scored, the adults were discarded into a milk bottle and the larvae were placed in another bottle. Both bottles were about 3/4 filled with unbleached wheat flour, and remained unplugged during these observations. As the density of larvae or adults increased in these bottles the medium underwent the changes described above and in Lezcano and Sokoloff's paper. The flour in the bottle containing larvae soon became very moist and there were droplets of moisture developing on the walls of the bottle. The medium

became moldy, and as the medium started to dry it formed a plug which gradually became detached from the inner walls of the glass bottle. The beetle larvae were either driven to the surface or were trapped in the plug.

At this point I noted that there were some Diptera larvae crawling on the surface of the medium. Some adult flies were seen going in and out of the uncapped bottle. They proved to be humpbacked flies (Family Phoridae), whic previous experience had shown that they can be easily raised to a culture in Drosophila medium. The flies run in jerky movements, and they seem pretty aggressive, often landing on one's face and hands. According to Borror, Triplehorn and Johnson, 1989 "phorids are small or minute flies that are easily recognized by their humpbacked appearance, characteristic venation, and the laterally flattened hind femora. The adults are fairly common in many habitats, but most abundant about decaying vegetation. The habits of the larvae are varied; some occur in decaying animal or vegetable matter; some occur in fungi; some are internal parasites of various other insects; and some occur as parasites or comensals in the nests of ants or termites. A few of the species that occur in ant or termite nests (and some others as well) have the wings reduced or lacking. More than 350 species occur in our area".

When phorid larvae were noticed, the bottle was plugged. The larvae pupated, and eventually about 100 adults emerged, making it possible to identify this fly readily to the family Phoridae.

Although such successional changes of one organism to another on the same medium are artificial, nevertheless, as these observations show, it is possible for organisms whose larvae live in a xeric habitat (in the present case Tribolium freemani) to be succeeded by organisms whose larval habitat is mesic (flies of the family Phoridae).

It is doubtful that these two organisms, Tribolium and the humpbacked flies, would ever come into an association under normal circumstances. However, Tribolium has been reported to consume the flesh of dead birds or insects, and phorids appear to be opportunistic scavengers. So, if the opportunity presented itself, flour beetles and flies may enter into a competitive relationship.

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NOTE: THESE REFERENCES HAVE BEEN OBTAINED FROM THE AGRICOLA DATABASE MAINLY FOR THE YEARS 1983-1992. THEY HAVE BEEN ARRANGED ACCORDING TO TOPIC TO CONFORM WITH THE FORMAT EMPLOYED IN THE TIB SINCE ITS INCEPTION IN 1958. THE EDITOR HOPES THIS COMPILATION AND ITS FORMAT WILL BE USEFUL TO THE SUBSCRIBERS OF TIB. THE EDITOR WOULD LIKE TO HEAR FROM COLLEAGUES TO LEARN WHETHER THIS APPROACH SHOULD BE FOLLOWED IN THE FUTURE FOR DATABASES COMPILED FOR EARLIER YEARS.

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