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STUDIES ON THE FECULAE OF SELECTED MICHIGAN ACRIDIDAE (ORTHOPTERA)[1]

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INTRODUCTION

Feculae have been used for some years in the study of insect food-habits and biology. Among the past authors who have used them are Frost (1928), Hodson and Brooks (1956), and Morris (1942), who discussed the use of feculae and frass in the identification of insect species in general; Boldyrev (1928), who figured the feculae of the bradyporine katydid *Bradyporus multituberculatus;* Brown (1937), who described in detail fecular microstructure in the spine-breasted grasshopper *Melanoplus bivittatus;* Weiss and Boyd (1950, 1952), who figured the feculae of representatives of selected insect orders; Gangwere (1962), who described the various factors responsible for shaping and coloring feculae, and with Morales (Gangwere and Morales, 1964) erected the first formal classification of orthopteroid feculae, and later (Gangwere, 1969) discussed the use of feculae of museum specimens as a shortcut method for determining food-habit; Scott (1964), who constructed a pictorial key to the droppings of cockroaches; Simeone (1964), who described the frass of posting beetles; Bhatia and Chandra (1967), who discussed the effect of food plants on the color, structure, and size of feculae in the locust *Schistocerca gregaria;* and Sardesai (1969) who reported on size variation in feculae of larval Lepidoptera.

With the partial exception of Gangwere and Morales (1964) and Bhatia and Chandra (1967), investigators have paid scant attention to variations in fecular structure within given species. The present study fills, in part, this gap in our knowledge. It describes those differences in fecular size and structure in selected Michigan acridids that relate to sex of defecator and type of food. It also attempts a statistical measurement of such differences.

MATERIALS AND METHODS

During the field seasons of 1964 and 1965, individuals of several species of Acrididae were collected at the Edwin S. George Reserve, Livingston County, Michigan, and, during the summer of 1968, at the Proud Lake and the Pontiac Lake Recreation Areas, Oakland County, and the Stony Creek Metropolitan Park, Macomb County, Michigan. The captured insects were maintained both in the field and in the laboratory using the rearing cages described in Gangwere (1960).

All animals from the E. S. George Reserve were caged in the field. They were isolated in individual mantid-type cages, as described by Gangwere (1960). The cages were placed on a table within a box-like wire window screening enclosure approximately 4 ft. x 4 ft. x 3 ft., and the table, in turn, was left uncovered in the field. Inasmuch as the cages were exposed to the out-of-door conditions, all testing was necessarily restricted to periods of good weather. Preparatory to a given test, each individual animal was starved for a period of 24 hours (emptying the gut), and then was allowed to feed on a single, known species of plant presented in a small Erlenmeyer flask. No other food was given, though each insect had access to water from a cotton-stoppered vial. Both animals and feculae were needed for study and measurement; thus, at the end of the feeding period, the insects were killed and preserved in 80% alcohol, and their feculae were harvested from the cage floors.

The animals from all stations other than the E. S. George Reserve were treated in a similar manner, except that all tests upon them were carried out in the laboratory and in absence of the protective screen enclosure.

[1]Contribution No. 246 from the Department of Biology, Wayne State University, Detroit, Michigan 48202. Based in part on a 1969 thesis submitted by Tyrkus in partial fulfillment of the requirements for the degree of Master of Science, Wayne State University, and in part research by Gangwere.

The length of all feculae was measured in the laboratory under a binocular compound microscope using an ocular micrometer. The length of the animals was taken with the method of Gangwere and Morales (1964); it was based on the distance between the anteriormost extension of the head capsule and the apex of the hind femur (with the latter placed so that its long axis is parallel to the body). This measurement was accomplished under a binocular dissecting microscope by placing the animal in question against a rule, and was standardized by use of an ocular micrometer.

The species investigated include the following:

Acrididae: Oedipodinae (Band-Winged Grasshoppers)

Arphia p. pseudonietana (Thomas)
Spharagemon b. bolli Scudder
Spharagemon collare (Scudder)

Acrididae: Catantopinae (Spine-Breasted Grasshoppers)

Melanoplus confusus Scudder
Melanoplus s. sanguinipes (Fabricius)

RESULTS

The results of the study are presented entirely in tabular form. They include Table 1 (Studies on the Feculae of Selected Acrididae: Basic Data), Table 2A (Size Variation in Defecating Animals and their Respective Feculae), Table 2B (Size Variation in Defecating Animals and their Feculae: By Fecular Type), and Table 3 (One-Way Analysis of Variance for Variable Ratios Between Various Populations and Groups).

Table 1. Studies on the feculae of selected Acrididae: basic data.

Plants ingested	Feeders[2]	Sex	Ave. Length Feculae (mm)	Ave. Length Defecators (mm)	Ratio of Lengths	Types of Feculae[3]
Equisetaceae						
Equisetum arvense	MC	F	5.10	22	1:4.31	1B
Moss sp.	SC	M	3.96	20	1:5.05	1C
Gramineae						
Aristida purpurascens	MC	F	4.65	21	1:4.52	1C
” ”	MS	F	5.34	22	1:4.10	1B
” ”	AP	F	7.56	23	1:3.04	1B
” ”	SB	F	6.14	28	1:4.56	1B
” ”	SC	M	4.39	22	1:5.02	1B
Cenchrus sp.	AP	M	3.83	21	1:5.49	1B
Danthonia spicata	MC	F	4.50	20	1:4.44	1B
” ”	SC	F	6.24	22	1:3.53	1B
Eragrostis spectabilis	SB	F	4.26	–	-----	1B
Leptoloma cognatum	MS	F	4.97	20	1:4.01	BC
” ”	AP	F	7.16	22	1:3.07	1B
” ”	SC	M	4:12	19	1:4.61	BC
Panicum depauperatum	SC	M	2.67	19	1:7.10	1B
” ”	SC	F	5.21	24	1:4.61	1B
Panicum oligosenthes	MC	F	4.01	19	1:4.01	1B
” ”	MS	M	4.75	17	1:3.58	BC
” ”	AP	M	4.21	21	1:4.99	1B
” ”	SB	F	3.17	26	1:8.20	1B
” ”	SC	M	4.19	19	1:4.54	1B

Table 1 (Continued)

Poa compressa	MC	F	4.56	21	1:4.61	1B
" "	MS	M	4.42	16	1:3.62	1B
" "	AP	M	5.25	23	1:4.38	1B
" "	AP	F	5.25	25	1:4.76	1B
" "	SB	F	5.88	26	1:4.42	1B
" "	SC	F	4.96	22	1:4.43	1B
Poa pratensis	MS	F	5.34	22	1:4.10	1B
" "	AP	M	---	21	-----	1B
" "	SB	M	3.22	–	-----	1B
" "	SC	M	3.47	21	1:6.05	1B
" "	SC	M	4.42	20	1:4.52	1B
Setaria glauca	AP	F	4.70	24	1:5.11	1B
" "	SC	F	5.31	25	1:4.71	1B
Cyperaceae						
Carex muhlenbergii	MC	·M	2.08	18	1:8.65	BC
Cyperus filiculmis	MC	M	3.28	16	1:4.88	1B
" "	MS	M	3.41	20	1:5.86	BC
" "	AP	M	7.37	22	1:2.98	1B
" "	SB	F	5.03	–	-----	1B
" "	SC	M	4.16	19	1:4.57	1C
Cupressaceae						
Juniperus sp.	MC	F	4.16	22	1:5.29	1B
Polygonaceae						
Rumex acetosella	MC	F	2.97	22	1:7.41	1B
" "	MS	M	3.55	18	1:5.08	1C
" "	AP	M	3.07	22	1:7.17	BC
" "	SB	F	6.14	29	1:4.72	1C
" "	SC	F	4.21	23	1:5.46	1C
Cruciferae						
Lepidium virginicum	MC	F	3.44	19	1:5.52	1C
Rosaceae						
Potentilla intermedia	MC	F	3.32	19	1:5.72	1B
" "	SC	M	3.73	20	1:5.36	1C
" "	SC	M	3.53	19	1:5.38	1C
Rubus flagellaris	MC	M	2.28	17	1:8.17	1C
" "	MC	M	2.50	17	1:6.80	1C
" "	MS	F	3.37	–	-----	1C
" "	AP	M	3.92	22	1:5.61	1C
" "	SC	M	3.00	20	1:6.67	1C
Juglandaceae						
Carya ovalis	MS	F	2.89	20	1:6.92	1C
" "	SC	M	3.07	19	1:6.19	1C
Carya sp.	MC	F	3.12	19	1:6.09	1B
" "	MC	M	2.35	–	-----	1C
Fabaceae						
Desmodium illinoense	MC	M	2.48	17	1:6.88	1C
" "	AP	M	3.47	21	1:6.05	BC
" "	AP	F	6.31	28	1:4.43	BC
Desmodium sessilifolium	AP	M	3.41	21	1:6.15	1C
Lespedeza capitata	MC	F	4.28	19	1:4.49	1C
" "	MS	F	3.47	19	1:5.47	1C
" "	AP	F	9.56	26	1:2.72	1C

Table 1 (Continued)

Lespedeza capitata	SB	F	5.43	27	1:4.97	1B
" "	SC	F	4.55	24	1:5.27	1C
Lespedeza hirta	MC	M	2.72	17	1:6.25	1C
" "	AP	F	3.66	24	1:6.56	1C
" "	SC	F	5.15	25	1:4.85	--
Oxalidaceae						
Oxalis stricta	MC	F	3.66	22	1:6.01	1B
" "	MS	F	3.56	20	1:5.62	1C
" "	AP	M	2.18	22	1:10.09	1C
" "	SC	M	4.11	20	1:4.87	1C
Fagaceae						
Quercus rubra	SC	F	4.13	22	1:5.33	1C
Quercus sp.	MC	M	2.65	21	1:7.92	1C
Euphorbiaceae						
Euphorbia corollata	AP	F	3.33	25	1:7.51	BC
" "	SB	F	2.89	30	1:10.38	1C
" "	SC	F	5.44	24	1:4.41	BC
Hypericaceae						
Hypericum perforatum	MC	M	2.72	17	1:6.25	1C
" "	MC	F	4.21	21	1:4.99	1C
" "	MS	M	3.27	20	1:6.11	1C
" "	SC	F	3.47	23	1:6.63	1C
" "	SC	F	5.74	23	1:4.01	1C
Cistaceae						
Helianthemum canadense	MC	M	2.45	17	1:6.94	1C
Lechea villosa	MS	F	3.68	22	1:5.99	1C
" "	AP	F	3.96	26	1:6.57	1C
" "	SC	M	2.73	21	1:7.69	1C
Umbelliferae						
Daucus carota	MC	F	3.94	23	1:5.85	1C
Asclepiadaceae						
Asclepias syriaca	MC	F	3.57	19	1:5.32	1C
" "	MC	F	3.31	20	1:6.05	1C
" "	MS	F	2.90	20	1:6.89	1C
" "	SB	F(nymph)	6.11	22	1:3.60	1C
" "	SC	F	2.57	20	1:7.79	1C
Verbenaceae						
Verbena sp.	MC	F	4.19	20	1:4.77	1C
Labiatae						
Leonurus cardiaca	MC	F	4.06	21	1:5.17	1C
Monarda fistulosa	MS	F	2.97	22	1:7.41	1C
" "	AP	M	3.76	21	1:5.58	1C
" "	SC	F	4.90	24	1:4.90	1C
Solanaceae						
Physalis heterophylla	MC	F	3.86	20	1:5.18	1C
" "	MS	F	4.03	21	1:5.21	1C
" "	SC	M	2.67	18	1:6.74	BC
Plantaginaceae						
Plantago aristata	MC	F	2.87	21	1:7.32	1C
" "	MS	M	3.17	18	1:5.68	1C
" "	SC	M	4.16	20	1:4.81	1C
" "	SC	M	4.26	19	1:4.46	1C

Table 1 (Continued)

Plantago rugelii	SC	M	3.08	21	1:6.82	1C
Compositae						
Achillea millefolium	AP	F	6.14	25	1:4.07	1C
” ”	SC	M	4.36	20	1:4.59	1C
Ambrosia artemisiifolia	MC	F	2.99	21	1:7.02	1C
” ”	AP	F	3.91	24	1:6.14	1C
” ”	SB	M	3.80	22	1:5.79	1C
” ”	SC	M	2.77	19	1:6.86	1C
Antennaria fallax	MC	M	3.17	19	1:6.00	1C
Antennaria neglecta	MC	M	2.63	18	1:6.85	1C
” ”	MC	F	3.47	20	1:5.76	1C
” ”	MS	M	2.89	19	1:6.59	1C
” ”	AP	M	3.96	21	1:5.33	1C
” ”	SC	M	3.81	20	1:5.25	BC
” ”	SC	M	3.62	20	1:5.52	BC
Arctium minus	MC	F	4.60	20	1:4.35	1C
Chrysanthemum leucanthemum	MC	M	3.12	18	1:5.77	1C
Erigeron strigosus	MC	F	4.36	25	1:5.71	1C
” ”	MS	F	4.21	22	1:5.22	1C
” ”	SB	F	4.72	–	-----	1C
” ”	SC	F	3.46	24	1:6.94	1C
Gnaphalium obtusifolium	AP	F	4.06	25	1:6.15	1C
” ”	SC	F	2.09	24	1:11.48	1C
Hieracium gronovii	MC	F	3.83	21	1:5.48	1C
” ”	SB	F	5.45	25	1:4.59	1C
” ”	SC	F	3.40	25	1:7.35	1C
Hieracium longipilum	MC	F	4.85	22	1:4.54	1C
” ”	MC	M	3.25	17	1:5.23	1C
” ”	MS	M	4.21	19	1:4.51	1C
” ”	MS	F	4.23	15	1:3.54	1C
” ”	AP	F	6.47	26	1:4.02	BC
” ”	AP	M	3.71	22	1:5.93	1C
” ”	SB	F	6.19	28	1:4.52	1C
” ”	SC	M	4.31	19	1:4.41	BC
” ”	SC	M	4.16	19	1:4.57	BC
Hieracium sp.	MS	F	3.56	21	1:5.89	1C
Lactuca sp.	MC	F	4.39	20	1:4.55	1C
Liatris aspera	MC	M	2.70	17	1:6.28	1C
” ”	MC	M	2.92	18	1:6.16	1C
” ”	MS	M	3.31	17	1:5.13	1C
” ”	SB	M	2.81	21	1:7.47	1C
” ”	SC	M	5.34	19	1:3.55	1C
Solidago juncea	MC	F	3.09	21	1:6.79	1C
” ”	MC	F	4.61	23	1:4.99	1C
” ”	MC	F	3.04	19	1:6.25	1C
” ”	MS	M	3.76	19	1:5.05	1C
Solidago nemoralis	MC	F	3.52	21	1:5.97	1C
” ”	MS	M	2.77	18	1:6.85	1C
” ”	SB	F	4.46	31	1:6.95	1C
” ”	SB	M	2.65	20	1:7.55	1C
Solidago rigida	MS	F	3.63	20	1:5.50	1C
” ”	AP	M	3.78	22	1:5.82	BC
” ”	SB	F	3.60	–	-----	1C

Table 1 (Continued)

Taraxacum officinale	AP	M	—	23	----	1C
Tragopogon pratensis	MC	F	4.21	21	1:4.99	1C
" "	MC	F	5.77	21	1:3.64	1C
" "	MS	F	3.36	20	1:6.00	1C
" "	SC	F	4.65	23	1:4.95	1C
Verbascum thapsus	SC	M	3.10	18	1:5.81	1C

[2]Feeding species are denoted by the following code: MC = Melanoplus confusus, MS = Melanoplus s. sanguinipes, AP = Arphia p. pseudonietana, SB = Spharagemon bolli, SC = Spharagemon collare.
[3]Based on Gangwere (1962).

Table 2A. Size variation in defecating animals and their respective feculae.

Groups and Species Tested	Fecular N[4]	Defecator N[4]	Mean Fecular Length (mm)	Mean Defecator Length (mm)	Mean Variable Ratio[5]
Males, all species	66	68	3.5121	19.5294	0.1806
Females, all species	90	90	4.4576	22.211	0.2252
Acrididae: Oedipodinae					
Arphia p. pseudonietana	26	28	4.7688	22.3214	0.2971
A. p. pseudonietana (males)	13	15	3.9938	21.6667	0.1845
A. p. pseudonietana (females)	13	13	5.5438	23.0769	0.4097
Spharagemon b. bolli	13	13	4.7015	25.7692	0.1828
S. b. bolli (males)	3	3	3.0867	21.0000	0.1463
S. b. bolli (females)	10	10	5.1860	27.2000	0.1937
Spharagemon collare	44	44	3.9768	21.0227	0.1892
S. collare (males)	27	27	3.6852	19.5556	0.1885
S. collare (females)	17	17	4.4400	23.3529	0.1902
Acrididae: Catantopinae					
Melanoplus confusus	48	48	3.7298	19.9375	0.1847
M. confusus (males)	13	13	2.6754	17.6154	0.1525
M. confusus (females)	35	35	4.1214	20.8000	0.1966
Melanoplus s. sanguinipes	25	25	3.7544	19.4000	0.1958
M. s. sanguinipes (males)	10	10	3.6340	18.3000	0.2007
M. s. sanguinipes (females)	15	15	3.8347	20.1333	0.1926

[4]N = number
[5]Variable ratio = defecator length/fecular length

Table 2B. Size variation in defecating animals and their feculae: by fecular type.

Types of Feculae[6]	Fecular N[7]	Defecator N[7]	Mean Fecular Length (mm.)	Mean Defecator Length (mm.)	Mean Variable Ratio[8]
1B	33	34	4.7521	21.0588	0.2918
1C	104	105	3.8388	21.0952	0.1815
BC	16	16	4.2306	21.2500	0.1995

[6]Based on Gangwere (1962).
[7]N = Number
[8]Variable ratio = defactor length/fecular length.

Table 3. One-way analysis of variance for variable ratios (feculae: animal) between various populations and groups.

Populations or Groups Tested	N 1	N 2	Mean Variable Ratio 1	Mean Variable Ratio 2	t Value	Probability[9] (P)	Significance
Type 1B: Type 1C	33	104	0.2918	0.1815	2.6303	0.001 ⩽ P ⩽ 0.01	(+)
Type 1B: Type BC	33	16	0.2918	0.1995	0.8692	0.4 ⩽ P ⩽ 0.5	(-)
Type 1C: Type BC	104	16	0.1815	0.1995	1.3585	0.1 ⩽ P ⩽ 0.2	(-)
Total ♂: Total ♀	66	90	0.1806	0.2252	1.3704	0.1 ⩽ P ⩽ 0.2	(-)
Melanoplus confusus ♂ & ♀: *Melanoplus sanguinipes* ♂ & ♀	48	13	0.1847	0.1828	0.1160	0.5 ⩽ P	(-)
Melanoplus confusus ♂ & ♀: *Arphia p. pseudonietana* ♂ & ♀	48	26	0.1847	0.2971	1.6152	0.1 ⩽ P ⩽ 0.2	(-)
Spharagemon b. bolli ♂ & ♀: *Spharagemon collare* ♂ & ♀	13	44	0.1828	0.1892	0.4593	0.5 ⩽ P	(-)
Spharagemon b. bolli ♂ & ♀: *Melanoplus sanguinipes* ♂ & ♀	13	25	0.1828	0.1958	0.8061	0.4 ⩽ P ⩽ 0.5	(-)
Spharagemon b. bolli ♂ & ♀: *Arphia p. pseudonietana* ♂ & ♀	13	26	0.1828	0.2971	0.8510	0.4 ⩽ P ⩽ 0.5	(-)
Spharagemon collare ♂ & ♀: *Melanoplus sanguinipes* ♂ & ♀	44	25	0.1892	0.1958	0.6266	0.5 ⩽ P	(-)
Spharagemon collare ♂ & ♀: *Arphia p. pseudonietana* ♂ & ♀	44	26	0.1892	0.2971	1.4906	0.1 ⩽ P ⩽ 0.2	(-)
Melanoplus sanguinipes ♂ & ♀: *Arphia p. pseudonietana* ♂ & ♀	25	26	0.1958	0.2971	1.0511	0.2 ⩽ P ⩽ 0.3	(-)
Melanoplus confusus ♂: *Melanoplus confusus* ♀	13	35	0.1525	0.1966	2.7663	.001 ⩽ P ⩽ 0.01	(+)
Melanoplus confusus ♂: *Spharagemon b. bolli* ♂	13	3	0.1525	0.1463	0.4274	0.5 ⩽ P	(-)
Melanoplus confusus ♂: *Spharagemon collare* ♂	13	27	0.1525	0.1885	3.2228	0.001 ⩽ P ⩽ 0.01	(+)
Melanoplus confusus ♂: *Melanoplus sanguinipes* ♂	13	10	0.1525	0.2007	3.2944	.001 ⩽ P ⩽ 0.01	(+)
Melanoplus confusus ♂: *Arphia p. pseudonietana* ♂	13	13	0.1525	0.1845	1.9570	0.05 ⩽ P ⩽ 010	(-)
Melanoplus confusus ♀: *Spharagemon b. bolli* ♀	35	10	0.1966	0.1937	0.1464	0.5 ⩽ P	(-)
Melanoplus confusus ♀: *Spharagemon collare* ♀	35	17	0.1966	0.1902	0.4052	0.5 ⩽ P	(-)
Melanoplus confusus ♀: *Melanoplus sanguinipes* ♀	35	15	0.1966	0.1926	0.2522	0.5 ⩽ P	(-)
Melanoplus confusus ♀: *Arphia p. pseudonietana* ♀	35	13	0.1966	0.4097	1.8985	0.05 ⩽ P ⩽ 0.10	(-)
Spharagemon b. bolli ♂: *Spharagemon b. bolli* ♀	3	10	0.1463	0.1937	1.4102	0.1 ⩽ P ⩽ 0.2	(-)
Spharagemon b. bolli ♂: *Spharagemon collare* ♂	3	27	0.1463	0.1885	1.9201	0.05 ⩽ P ⩽ 0.1	(-)

Table 3 (Continued)

Spharagemon b. bolli ♂: *Melanoplus sanguinipes* ♂	3	10	0.1463	0.2007	1.9228	0.05 ⩽ P ⩽ 0.1	(–)
Spharagemon b. bolli ♂: *Arphia p. pseudonietana* ♂	3	13	0.1463	0.1845	1.1662	0.2 ⩽ P ⩽ 0.3	(–)
Spharagemon b. bolli ♀: *Spharagemon collare* ♀	10	17	0.1937	0.1902	0.1707	0.5 ⩽ P	(–)
Spharagemon b. bolli ♀: *Melanoplus sanguinipes* ♀	10	15	0.1937	0.1926	0.05862	0.5 ⩽ P	(–)
Spharagemon b. bolli ♀: *Arphia p. pseudonietana* ♀	10	13	0.1937	0.1845	0.3994	0.5 ⩽ P	(–)
Spharagemon collare ♂: *Spharagemon collare* ♀	27	17	0.1885	0.1902	0.1336	0.4 ⩽ P ⩽ 0.5	(–)
Spharagemon collare ♂: *Melanoplus sanguinipes* ♂	27	10	0.1885	0.2007	0.8333	0.4 ⩽ P ⩽ 0.5	(–)
Spharagemon collare ♂: *Arphia p. pseudonietana* ♂	27	13	0.1885	0.1845	0.2746	0.5 ⩽ P	(–)
Spharagemon collare ♀: *Melanoplus sanguinipes* ♀	17	15	0.1902	0.1926	0.1406	0.5 ⩽ P	(–)
Spharagemon collare ♀: *Arphia p. pseudonietana* ♀	17	13	0.1902	0.4097	1.3532	0.1 ⩽ P ⩽ 0.2	(–)
Melanoplus sanguinipes ♂: *Melanoplus sanguinipes* ♀	10	15	0.2007	0.1926	0.4455	0.5 ⩽ P	(–)
Melanoplus sanguinipes ♂: *Arphia p. pseudonietana* ♂	10	13	0.2007	0.1845	0.7541	0.4 ⩽ P ⩽ 0.5	(–)
Melanoplus sanguinipes ♀: *Arphia p. pseudonietana* ♀	15	13	0.1926	0.4097	1.2557	0.2 ⩽ P ⩽ 0.3	(–)

[9]p = the probability that a t value equal to that observed can be obtained by chance alone.

DISCUSSION

In terms of Gangwere's classification of feculae of orthopteroids (1962), the feculae of the species of Acrididae here investigated belong to types 1B (Fig. 1), 1C (Fig. 3), and BC (an intermediate between 1B and 1C) (Fig. 2). Type 1B feculae were described by Gangwere as typical of the Oedipodinae and Type 1C as typical of the Catantopinae. The former pellets, which are composed of somewhat aligned fibers, are comparatively regular and spindle-shaped in form, while the latter are always wrinkled, irregular, and unaligned. The occurrence of these three types is closely related to food. It was noted during the present study that grasses and their relatives consistently give rise to Type 1B feculae; Compositae and other "higher" forbs to Type 1C; and herbs phylogenetically intermediate between grasses and "higher" forbs to Type BC. These differences are interpreted as directly related to food composition.

Type 1B feculae are generally longer in comparison with length of defecator than are either types 1C or BC feculae. Type 1B feculae averaged approximately 29% of defecator length, Type 1C 18% and the intermediate BC 20% for the total number of animals measured (Table 2B, column 6).

The collective feculae of all females measured are larger than are those of the males, and this absolute difference in size is apparently related to the size differential between the sexes. Males of all species studied averaged 19.5294 mm. in body length, while the females

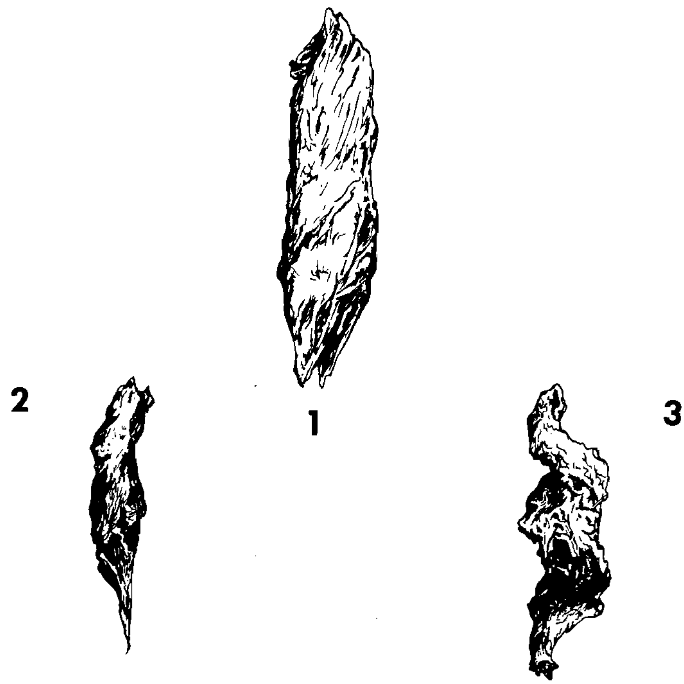

Fig. 1. Aligned fecula (Type 1B) of a grass-fed *Chortophaga viridifasciata* (Orthoptera: Acrididae: Oedipodinae).

Fig. 2. Poorly aligned fecula (Type BC) of a thistle-fed *Chortophaga viridifasciata.*

Fig. 3. Unaligned fecula (Type 1C) of a lettuce-fed *Chortophaga viridifasciata.*

averaged 22.211 mm. Thus, the feculae produced by the males are approximately 18% of the total body length, as opposed to those of the females, which approach 23% (Table 2A, column 6).

The larger species tend, in general, to have a greater average fecular length (Table 2A, column 6). However, the relative ratio of fecular length to length of body is relatively constant at 18 to 20% for all species, except *Arphia p. pseudonietana,* where the ratio is approximately 30%, possibly in response to that species' almost complete graminivory.

The males of a given species of acridid are always smaller than are the females, and with one exception have a correspondingly lesser ratio of fecular length to body length (Table 2A, column 6). However, this difference between the sexes is statistically insignificant (Table 3, column 8), ruling out the possibility of a physiological sexual dimorphism of the digestive system. *Melanoplus s. sanguinipes* proved to be the only exception to the rule of a higher ratio among the female sex. In this species, females average 1.8 mm. longer than do the males, but have a fecular length-body length ratio that is 1% lower than that of the males (Table 2A, column 6). This disparity, too, is statistically insignificant (Table 3, column 8).

The fecular length-body length ratio may now be considered as a function of food plant. Scrutiny of Table 2B (column 6) indicates that Type 1B feculae (composed of grasses and their allies) exhibit a higher ratio (29%) than do the forb-type 1C feculae (18%). Moreover, this disparity proves statistically significant (Table 3, column 8), which confirms the validity of the acridid fecal types proposed by Gangwere (1962).

One-way analysis of variance tests on the ratio of fecular length to animal length between various populations and groupings is also possible, and is here carried out. The results appear in Table 3. Based on that tabulation, males and females—regardless of species—show no significant differences in their ratios, and the individual species—regardless of sex tested—also show no significant differences. Indeed, of all possible combinations of species and sex tested, only those differences between the males of *Melanoplus confusus* and those of *M. s. sanguinipes;* the males of *M. confusus* and those of *Spharagemon collare;* and the males and the females of *M. confusus* prove significant (Table 3, column 8). These few significant differences could be related to some yet unstudied biological factor, but are more likely a result of the small sample size of *M. confusus* males.

SUMMARY AND CONCLUSIONS

The length of the acridid feculae here studied is in part related to size of defecator and in part to composition of food. The length of Type 1B feculae proves primarily a consequence of food source (being always formed of grasses), while that of Type 1C feculae is more closely related to size of defecator than to food. As expected, the intermediate Type BC feculae are intermediate in this respect. The conformation of acridid feculae (as opposed to pure length, above) is determined by the food composition. Thus, the tendency of acridids to select assortments of food species from only a few fundamentally different kinds of plants (*i.e.*, grasses, forbs, shrubs, etc.) leads inevitably to the production of a limited number of fecal types. These types were earlier named by Gangwere (1962), based on comparative length, alignment, and shape, and the validity of the acridid types that he proposed is statistically confirmed by the present study. It appears that, in general, the length and form of the feculae of grasshoppers is determined by the combined influence of defecator length and food plant composition, with food exerting the greater effect. It is most certainly *not* related to the taxonomic position of the defecator. Consequently, it is here concluded that the feculae of grasshoppers are unsuitable objects for use in systematics, except in those relatively few species of the world-wide fauna that are highly specialized in their food selection.

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