Rec. zool. Surv. India, 72 : 341-361, 1977

VARIATIONS IN THE KNOWN VARIATION-STABLE (*PHASE GREGARIA*) POPULATION OF THE DESERT LOCUST *SCHISTOCERCA GREGARIA* FORSKAL

By

R. K. BHANOTAR and Y MAHTO

Entomology Division, IARI, New Delhi-12

(with 6 tables and 1 plate)

The species *Schistocerca gregaria* undergo periodic population explosion. During the swarming or plague years its distribution covers three continents affecting 66 countries of the old world and spreading over 16.5 million square miles. This plague period alternates with non-swarming years or recession period which is restricted to 9.5 million square miles (Roonwal, 1954).

Polymorphic aspect of this species is now well known (Uvarov 1923, 1928). The two Uvarovian phase individuals differ from each other in size, proportion of body-parts and colour. The two extreme forms react differently in physiology and behaviour. "The phase polymorphism involves a whole complex of responses of an individual to the population density. Some responses to density are immediate while others are cumulative in the course of several generations (Uvarov 1966)."

The morphological variation in phase polymorphism have been worked out by several workers. In general phase *solitaria* is considered far more variable than phase *gregaria*. The most sensitive character which indicates significant differences in two phases is width of head at genal level (C). However, 20 different body parts and their indices signify phase difference.

"Solitaria" individuals as variation unstable

That there is a flowering of variations in *solitaria* phase individuals is ably demonstrated by Roonwal (1954). He discovered the occurence of three types of eye-stripe polymorphs in solitarious populations the 6-, 7-and 8-stripes, the number of moults also varying according to order thus, 5, 5-6 and 6-7 respectively. Similarly the number of antennal segments varies from 26-27, 28-29 and 30. The proportion of sexes

also differs among 6-, 7-and 8-srtiped individuals. Males (♂.60:♀40) predominating among 6-striped individuals, but females predominating over males in 7-(♂ 35 : ♀ 65) and 8- (♂ 29: ♀ 71) striped individuals. The other notable morphological differences in two extreme phases are the degree of sexual dimorphism, in the number of hind tibial spines and in the development of eye-stripes (Roonwal, 1954).

These maximum variation lead Roonwal (1954) to propound a new evolutionary effect, "Roonwal effect" or "A New Effect" according to which variation intensity in the Desert Locust is greatest in minimum population (*solitaria* or non-swarming years) and least in maximum populations (*gregaria* or swarming years). The "effect" further elucidate that (i) this effect is inversely proportional to population size and (ii) land area of distribution.

"Gregaria" individuals as variation stable

The *gregaria* phased individuals in the Desert Locust are variation-stable and only a single type of eye-stripe polymorph (6-eye-striped) occur. The almost uniformity in this phase is much worked out by various authors. The behaviour, physiology and morphometry of the individuals along with their indices and sex-ratios (♂ 50 : ♀50) are almost constant and there appears least over lapping in this respect.

Roonwal (1962) on the causes of polymorphism stated thus, "Phase polymorphism should be essentially regarded as a continuum between two extreme points-the *gregaria* and *solitaria*, the most important single factor governing the change from one point to another on this continuum is population density. On the other hand non-phase polymorphs are sharply separated and do not form a continuum."

Variations in the heitherto variation-stable (phase gregaria) populations.

Roonwal (1958, p. 84) on the evolutionary effects of population flux stated thus: "the existence of interspecific variability is the basis of speciation by which term we mean the process by means of which specific differences arise. Variation first arises in individuals and then spread to the group and speciation thus depends upon the behaviour of variability in natural populations. This behaviour is influenced by various factors called "pressures".

The desert locust, phase *gregaria* individuals in the natural field populations are known for their constancy in the morphometric charactors, behaviour and physiology. However, in the recent laboratory work at IARI, New Delhi, we have observed the appearance of variability in the individuals of crowded population as follows:

I—EMERGENCE OF GREEN AND BLACK HOPPERS FROM THE SAME EGG-POD.

Uvarov (1966, p. 333) have stated that heavier hatchlings from crowded parents, as a rule, are of darker and even almost black coloured. Where as under Delhi laboratory condition we have invariably came across 2-3 green coloured hatchlings emerging from each egg-pod from crowded stock from 2nd generation onwards. These hatchlings are usually weak and slower in action in the beginning and after few days readily respond to the colour of environment if isolated. The findings are similar to those of Chauvin (1941) and Hunter Jones (1958). In the later generations (F_4 and F_5), the number of such green hatchlings are much more. It is further noticed that from 3rd to 4th generation onward, the number of eggs per pod laid by females are considerably reduced even when the environment, density and food material remains the same. As a rule gregarious colour pattern is not subject to change is response to the colour of environment, where as *solitaria* hoppers readily adjust their coloration to it.

These green hatchlings take longer time of development (*solitaria* characteristics) for reaching adult stage than their counterparts from the same egg-pod. Thus it appears that some of the *gregaria* individuals, from crowded stock having *gregaria* antecedent, behave abnormally thereby creating a weakening tendency in the crowded stock. The morphometrics of such fledglings and adults may or may not become as those of solitarious populations but their behavioural aspect remains *gregarious*. In the natural field population of gregarious individuals similar activity might be happenning and light green hoppers must be emerging (although not recorded so far) and such adults born out of green hoppers may move along with their *gregaria* counter parts, even along with immigrating swarms and may even develop 7- or 8-stripes (Bhanotar and Mahto, 1974 and Mahto & Bhanotar *in press*), a *solitaria* characteristic, as happened in the *Dehradun swarm of 1954*, the study of which, on the basis of the occurrence of a 7-striped individual, made Roonwal (1955) to predict the weakening and decline of 1949-55 locust cycle in India. The colouration, body measurements and ratios indicated *solitaria* characteristics of the individual although 1954 was the peak year of that swarming cycle when the maximum number (174) of swams invaded India.

This may also be the answer and reason to Bhatia and Singh's (1959) discovery of three 7-striped adults among phase *gregaria* individual during 1958. In one instance it was obtained from laboratory bred crowded stock (without their mentioning as to after how many generations) and in other two instances from natural field populations with low density. Two of the individuals (on the basis of E/F ratios) were attributed to phase *gregaria* and one to phase *transiens*. Incidentally next year (1959) heralded the 10th (recorded) locust cycle in India.

TABLE 1: Morphometric measurements (in mm.) and related ratios of the 7-striped individuals obtained from crowded stock (IARI—population) along with statistical constants.

	BODY CHARACTERS						
S. No.	O	C	P	H	M	E	W_1
			Females				
1.	6.60	7.25	9.60	8.05	5.35	52.70	7.20
2.	6.80	7.30	9.90	8.25	5.85	51.95	6.85
3.	6.90	7.45	10.45	8.30	5.35	56.15	7.25
4.	6.65	7.40	10.45	8.45	5.90	53.30	7.35
5.	6.60	7.05	9.60	8.30	6.05	54.90	6.80
6.	6.85	7.40	8.80	8.05	6.05	53.60	7.40
7.	6.60	7.10	9.40	8.15	5.90	52.25	6.40
8.	6.90	7.45	10.45	8.60	6.30	58.05	7.00
9.	6.90	7.60	9.60	8.65	6.25	54.10	7.50
Total	60.80	66.00	88.25	74.80	53.00	487.00	63.75
Mean	— 6.75	— 7.33	— 9.80	8.31	5.88	54.11	7.08
	± 0.04	± 0.18	± 0.18	± 0.07	± 0.11	± 0.65	± 0.11
S. D.	± 0.14	± 0.55	± 0.56	± 0.21	± 0.34	± 1.97	± 0.35
C. V.	2.07	7.62	5.76	2.63	5.79	3.64	4.96
			Males				
1.	6.05	6.60	8.85	7.20	5.05	46.60	5.60
2.	6.00	6.35	8.45	7.35	4.90	45.65	6.20
Total	12.05	12.95	17.30	14.55	9.95	92.25	11.80
Mean	6.02	6.47	8.65	7.27	4.97	46.12	5.90
	± 0.02	± 0.12	± 2.07	± 0.07	± 0.07	± 0.47	± 0.30
S. D.	± 0.03	± 0.17	± 2.92	± 0.10	± 0.10	± 0.67	± 0.42
C. V.	5.98	2.73	2.07	1.46	2.13	1.45	7.19

Abbreviations: O, width of head at ocular level; C, width of head at genal level; P, length of pronotum at Keel; H, height of pronotum; M, width of pronotum at constriction; E, length of elytron; F, length of hind femur, W_1; width of elytron at M. Cu. vein.

RATIOS					
F	E/F	P/C	C/O	F/C	H/C
		Females			
24.90	2.11	1.32	1.09	3.43	1.11
—	—	1.32	1.09	—	1.11
24.90	2.25	1.40	1.07	3.34	1.11
26.00	2.05	1.35	1.11	3·51	1.14
24.60	2.23	1.36	1.06	3.48	1 17
24.75	2.16	1.18	1.08	3.34	1.08
24.15	2.16	1.32	1.16	3.40	1.15
25.35	2.25	1.40	1.07	3.40	1.15
20.15	2.06	1.26	1.10	3.44	1.13
194.80	17.27	11.91	9.83	27.34	10.15
24.35	2.15	1.32	1.09	3.41	1.12
± 0.62	± 0.02	± 0.028	± 0.01	± 0.02	± 0.009
± 1.78	± 0.08	± 0.06	± 0.03	± 0.06	± 0.02
7.25	3.73	5.23	2.74	1.77	2.39
		Males			
21.60	2.15	1.34	1.09	3.27	1.09
21.85	2.08	1.33	1.05	3.34	1.15
43.45	4.23	2.67	2.14	6.61	2.24
21.72	2.11	1.33	1.07	3.30	1.12
± 0.12	± 0.035	± 0.007	± 0.02	± 0.03	± 0.03
± 0.17	± 0.05	± 0.01	± 0.02	± 0.05	± 0.04
0.81	2.36	0.74	2.64	1.51	3.78

In another instance Roonwal and Misra (1952) obtained a 7-striped (male) in a small sample of 15 individuals from *Ajmer Swarm of June 1950*. The morphometrics of this 7-striped individual indicated *solitaria* features. Regarding this sample-population, Roonwal and Misra (1952, p. 113) stated that "the *Ajmer swarm* has some leanings towards the initial *Kakko concentration* of the previous year. This trend is further evident from the presence of one 7-striped individual even in a small sample of 15 individuals." Later Roonwal and Bhanotar (1966) while studying the biological association between the various pairs of characters and degree of gregarisation in three swarming populations concluded with respect to *Ajmer swarm* that it was evidently in the early stages of built up of the cycle and had not reached the "extreme *gregaria* phase"

The morphometric measurements along with related indices of such 7-striped individuals obtained from crowded stock as well as from green hoppers are given below (Table-I). Although the individuals have attained 7-stripes in behaviour and colouration they remained gregarious.

II—Occurrence of a 4-striped brachypterous female individual

(Tables 1-4)

This morph was obtained in the laboratory from the 4th generation of *gregaria* hoppers from a fairly crowded condition (306 hoppers) in a small sized cage (15″×15″×24″) during June-July '72 (temperature ranging between 30°c to 35°c). The first individual fromt his lot fledged after 24 days and the last after 30 days. All other adults of the stock had 6-stripes.

General features of the 4-striped individual

Body : subnormal, slender and shorter; *Colour*: dirty yellow; *Wings*: both fore and hind wings stumpy and crumpled; *Behaviour*: sedentary non-jumping type, crawling movement, not responding to the call of mature males; *Feeding*: less than normal; feacal pellets small, dark and less in number. Efforts for mating this individual were futile and the individual survived for 97 days. Incidentally this is the first ever report of an abnormal brachypterous 4-striped form in laboratory breeding.

Morphological characters:—Eyes small, lightly pigmented: 4-eye-stripes and 5 interstripes; antennal segments 14 and 15; abdominal segments -8; tibial spines:inner (13); outer (12).

Morphometric measurements (*in mm.*)

(1) Length of tibia-11.8
(2) Width of head at occular level (0)-4.15
(3) Width of head at genal level (C)-4.30

(4) Length of pronotum at keel (P)-5.40
(5) Height of pronotum (H)-5.00
(6) Width of pronotum at constriction (M)-5.20
(7) Length of elytron (E, left-side)-2.0
(8) Length of elytron (E. Right side)-4.35
(9) Length of femur (F)-12.85
(10) Body length-28.35

The related indices are: P/C (1.23); M/C(1.20); H/C (1.16); E/F left side' (0.165) and "right side" (0.360); E/C 'left side' (0.465) and "right side" (1.011) and F/C (2.80).

Ecological conditions:—The above 4-striped brachypterous morph was obtained in the laboratory culture kept under crowded condition which was subjected to sharp day and night fluctuation of temperature. The relative humidity percentage was fairly high. The antecedent or parentage of this specimen were of typical *gregaria* (dark-pink-coloured individuals) and were reared throughout earlier in crowded condition, all bearing 6-stripes with E/F ratios above 2.15 in all adults. The lots, were fed on cabbage leaves throughout.

Other types of variations in gregaria stock

Several of the individuals obtained after 3rd generation had considerable variations as follows:

(A) 5-striped male individual (Table-2)

A single individual was obtained with the following features and characteristics: (1) Antennal segments—25 (2) Abdominal segments as in all acridids ♂ 11, terg. 9 strn. (3) Tibial spines = inner 12, outer 10 (4) Tibial length = 15.60 mm.

TABLE 2.— Morphometric measurements (in mm) and ratios of 5-striped individual.

Body parts	Value	Ratios and their value
O—	4.55	P/C—1. 19
C—	4.90	M/C—0. 78
P—	5.85	
H—	5.40	H/C—1.102
M—	3.85	K/L—1. 75
K—	0.70	E/F—1. 72
L—	0.40	
E(R)—	28.00	R/T—1 52
F—	16.20	E/C—5. 71
R—	1.30	F/C—3. 30
T—	0.85	

Abbreviations:— K, max. width of metasternal interspace; L, mini. width of metasternal interspace; R, max. width of mesasternal interspace; T, mini. width of mesasternal interspace; For other abbreviations *see* Table I.

TABLE 3.—Morphometric measurements (in mm) and related ratios of variable individuals in 6-stripe cadtegory ('IARI-population) along with statistical constants.
Abbreviations : as in table 1 and 2.

S. N.	BODY CHARACTERS								
	O	C	P	H	M	K	L	E	F
					Females				
a.	5.75	6.50	8.20	6.95	5.35	1.20	0.75	R 28.5	19.2
b.	6.55	7.35	9.65	8.05	6.10	1.80	1.15	L 41.75 R 52.70	—
d.	6.35	7.15	8.95	7.85	5.75	1.05	0.90	L 6.60 R 51.0	23.1
e.	5.25	5.75	7.05	6.40	4.70	0.80	0.55	17.35	16.7
k.	6.15	6.90	8.35	7.45	5.85	1.00	0.60	R 23.35	L 22.1
l.	5.90	6.25	8.10	6.90	5.40	1.05	0.45	—	—
Total	35.95	39.90	50.30	43.60	33.15	6.90	4.40	L 65.70	59.0
Mean	5.99	6.65	8·38	7.26	5.52	1.15	0.733	21.90	19.6
	± 0.19	± 0.24	± 0.35	± 0.25	± 0.20	± 0.10	± 0.10	± 10.41	± 1.8
S. D.	± 0.46	± 0.59	± 0.87	± 0.62	± 0.492	± 0.25	± 0.25	± 18.01	± 3.2
C. V.	7.7	8.8	10.3	8.5	8.8	21.7	34.2	82.23	16.5
					Males				
c.	6.20	6.95	8.55	7.00	5.65	0.90	0.5	—	21.8
f.	5.55	6.05	—	6.55	4.90	0.70	0.40	—	18.9
g.	5.95	6.35	8.35	6.85	5.05	0.60	0.45	L 16.30 R 41.20	R 20.8
h.	5.90	6.35	7.90	6.85	5.35	0.75	0.45	R 23.80	—
i.	6.05	6.45	8.55	7.35	5.30	0.75	0.45	L 45.15 R 1·40	20.3
j.	5.95	6.45	7.85	7.05	5.05	0.95	0.50	L 13.40 R 44.15	R 20.8
Total	35.60	38.60	41.20	41.65	31.30	4.65	2.85	L 74.85	61.0
Mean	5.93	6.43	8.24	6.94	5.21	0.77	0.47	24.95	20.3
	± 0.08	± 0.11	± 0.15	± 0.10	± 0.11	± 0.05	± 0.02	± 1.64	± 0.8
S. D.	± 0.21	± 0.29	± 0.34	± 0.26	± 0.27	± 0.12	± 0.05	± 2.84	± 1.4
C. V.	3.64	4.53	4.12	3.81	5.19	16.64	10.94	11.38	7.3

RATIOS

	T	P/C	M/C	H/C	K/L	E/F	R/T	E/C	F/C
					Females				
5	1.10	1.26	0.82	1.06	1.60	1.48	1.59	4·8	2.95
5	1.65	1.31	0.82	1.09	1.56	—	1.30	L 5.66 R 7.17	—
0	1.60	1.25	0.80	1.09	1.16	L 0.28 R 2.20	1.43	L 0.92	2.95
0	1.20	1.22	0.81	1.11	1.45	1.03	1.25	3.01	2.90
0	1.10	1.21	0.84	1.07	1.60	1.05	1.36	3.38	3.20
5	1.30	1.29	0.86	1.10	2.33	—	1.26	—	—
5	7.95	7.54	4.95	6.52	9·70	L 3.84	8.19	L 17.35	12.00
0	1.32	1.25	0.82	1.08	1.61	0.96	1.36	3.47	3.00
3	± 0.1	± 0.01	± 0.008	± 0.007	± 0.15	± 0.24	± 0.05	± 0.08	± 0.67
3	± 0.24	± 0.03	± 0.02	± 0.01	± 0.38	± 0.49	± 0.12	± 1.75	± 0.13
3	18.4	3.04	2.54	1.65	23.60	51.04	9.45	50.43	45.00
					Males				
05	1.30	1.23	0.81	1.01	1.8	—	1.57	—	3.13
55	1.10	—	0.82	1.08	1.75	—	1.40	—	3.12
60	1.35	1.31	0.77	1.07	1.33	R 1.98	1.18	R 6.48	3.27
85	1.05	1.24	0.84	1.07	1.66	—	1.76	3.74	—
80	1.45	1.32	0.82	1.13	1.36	2.22	1.24	7.0	3.14
85	1.35	1.21	0.78	1.09	1.9	L 0.64 R 2.86	1.37	L 2.07 R 6.84	3.22
.70	7.60	6.31	4.84	6.45	9.80	L 2.86	8.52	L 12.81	15.88
.78	1.26	1.26	0.80	1.07	1.63	1.43	1.42	4.27	3.17
.07	± 0.06	± 0.02	± 0.10	± 0.01	± 0.09	± 0.78	± 0.08	± 1.44	± 0.29
.18	± 0.15	± 0.04	± 0.26	± 0.03	± 0.23	± 1.11	± 0.21	± 2.50	± 0.06
.26	12.40	3.88	3.22	3.53	1.40	77.62	14.78	58.71	2.04

* L., Left side and R, Right side.

Status of this morph is still not very clear, but it appears that it has some relation with the critical period of phase transformation. So far it has occurred thus:

(1) Mukerji and Batra (1938) obtained over a dozen individuals from two laboratory mass breeding at Baluchistan and Sind. These belonged to both the sexes including fully winged and brachypterous adults.

(2) Misra (1952) obtained a single male individual from a collection of 192 examples from Kakko village (Rajasthan) in July 1949 from a population density of 18780 per sq. mile. Incidentally 1949 was the initial year of the 1949-55 locust cycle in India.

(3) Roonwal and Bhanotar (1966) obtained two females from Gr. II population of 1955 (period May-August), the last year of 1949-55 cycle in India. These were correlated by them to the most crucial and critical period of phase transformation when the equilibrium of the characters appeared to be most shaken.

(4) Bhanotar *et. al.*, (1972) obtained a single male individual in 1971 from Gadra Road (out of 127 exs. collected). The population density was 18480 per 5 sq. km. It was from the same contiguous area that a loose swarm was formed during July 1972.

According to late Dr. Pradhan (verbal discussion) the occurrence of 5-striped individual in nature indicate a quick development process in the field population accomplished by sudden phase transformation.

(B) Other variations in the 6-striped gregaria individuals
(Tables 3 and 4)

Several instances of variabilities and abnormalities were noticed in 6-striped individuals bearing *gregaria* antecedents. The variable characters, their morphometrics and their departure value from normal or typical *gregaria* is given in tables 3 and 4 are as follows:

(a) *6-striped female*:—24 antennal segments; eye smaller both length and width wise; 13(inner) and 12 (outer) tibial spines; abdominal segments. The main variation is seen in the wings and elytron. The wings are very much crumpled and smaller; elytron not crumpled but smaller in size and length (28.5 mm) *ie*, 23.7 mm. reduced in length than the typical *gregaria* value. The values of other important sensitive characters such as C, P and F along with related indices P/C, E/F, and F/C are also lower than typical *gregaria* values. The individual died before attaining maturity. For values of other characters and ratios *see* Table-3.

(b) *6-striped female*; 25 antennal segments; eyes normal both length and width wise; abdominal segments 9. The main variation is seen in the elytron; wings normal; length of right elytron near normal (52.70 mm) but left elytron much smaller (41.75 mm.) *i.e.*, 16.26 mm. reduced

in length than the typical *gregaria* value. The values of other sensitive characters C and P along with related P/C value are also lower than typical *gregaria* values. The individual died before attaining maturity. For values of other characters and ratios *see* Table-3.

(c) 6-*striped mdle*: 27 antennal segments; eyes normal both length and width wise; abdominal segments 8; 13 (inner) and 13 (outer) tibial spines. The main variation is seen in the elytron and wings. Both elytron instead of lying on the lateral side have diagonally crossed over the abdomen from the middle. Wings 2/3rd of the body length. Tibial length 22.60 mm. The values of other sensitive characters C, P and F along with ratios P/C and F/C are also lower than typical *gregaria* values. For values of other characters and ratios *see* Table-3.

(d) 6-*striped female*: 25 antennal segments; eyes normal; abdominal segments 8; 13 (inner) and 11 (outer) tibial spines; tibial length 21.45 mm. The main variation is again seen in the elytron. Wings normal. The right elytron is near normal (51.0 mm) but the left elytron poorly developed. (6.60 mm) and crumpled. The values of other sensitive characters C, P and F and ratios P/C, E/F and F/C are also lower than typical *gregaria* values. For values of other characters and ratios *see* Table-3.

(e) 6-*striped female*: 25 antennal segments; eyes subnormal both length and width wise; 13 (inner) and 12 (outer spines); tibial length 16.50 mm; abdominal segments 8. The main variation is seen in the elytron and wings. Both elytron and wings poorly developed (17.35 mm). The values of other sensitive characters (C, P and F along with ratios P/C, E/F and F/C are lower than those in typical *gregaria*. For values of other characters and ratios *see* Table-3.

(f) 6-*striped male*: 26 antennal segments very much slender, black spots on many segments; eyes subnormal both length and width wise; abdominal segments 8; 13 (inner) and 14 (outer) tibial spines; tibial length 17.15 mm. The main variation is seen in the elytron and wing; no elytron and wings developed on right side, left elytron well developed but curved inward, left wing much slender and rudimentary right femur very much curved inwardly; right tibia curved at more than 90°, the adult could crawl only with hind legs raised and leaning on left side. The values of sensitive characters C and F and ratio F/C lower than those in typical *gregaria*. For values of other characters and ratios *see* Table-3.

(g) 6-*striped male*: 22 antennal segments eyes smaller than normal but comparatively wider; 14 (inner) and 13 (outer) tibial spines; abdominal segments 8; tibial length 19.55 mm. The main variations is seen in the elytron and wings; left elytron larger than hind-wing but both

poorly developed (16.30 mm.) less than half the length of right elytron, the right elytron (41.20 mm) and wings curved inward apically. The values of sensitive characters C, P, E and F and ratio E/F are lower than those in typical *gregaria* where as for ratios P/C and F/C these are higher. For values of other characters *see* Table-3.

TABLE 4.—Morphometric values (in mm.) of typical 6-striped males and females of phase *gregaria* and departure value from typical invariable individuals.

Abbreviations:—as in Table 1 and 2 and L and R left and right side of the body part respectively.

Characters and ratios	Variable individuals with departure value from normal sex with eye stripe							
	♂ (6)	♀ 6	sex with eye stripes					
			(a) 6 ♀	(b) 6 ♀	(c) 6 ♂	(d) 6 ♀		
C	7.55±0.045	7.89±0.074	<1.39	<0.54	<0.60	<0.74		
P	9.87±0.079	10.49±0.133	<2.29	<0.84	<1.32	<1.54		
E	52.85±0.52	58.01±0.81	<29.51	L<16.26 R< 5.31	—	L<51.41 R< 7.01		
F	24.32±0.20	26.44±0.37	<7.24	—	<2.52	< 3.29		
P/C	1.305±0.011	1.32±0.009	<0.064	<0.014	<0.075	<0.074		
E/F	2.17±0.024	2.25±0.017	<0.77	—	—	L<1.97 R<0.05		
F/C	3.233±0.32	3.320±0.032	<0.370	—	<0.103	<0.370		
Antennal segments	26	26	24	25	27	25		
(e) 6 ♀	(f) 6 ♂	(g) 6 ♂	(h) 6 ♂	(i) 6 ♂	(j) 6 ♂	(k) 6 ♀	(l) 6 ♀	
<2.14	<1.50	<1.20	<1.20	<1.10	<1.10	<0.99	<1.64	
< 3.44	—	<1.52	<1.97	<1.32	<2.02	<2.14	<2.39	
<40.66	—	L<36.55 R<11.65	R<29.05	L<7.70 R<51.45	L<39.45 R<8.70	R<34.66	—	
<9.74	<5.42	R<3.52	—	<4.02	R<3.52	L<4.34	—	
<0.104	—	>0.005	<0.065	>0.015	<0.095	<0.114	<0.034	
<1.22	—	R<0.19	—	>0.05	L<1.53 R<0.05	<1.20	—	
<0.420	<0.113	>0.37	—	<0.093	<0.013	<0.120	—	
25	26	22	24	26	26	26	23	

(h) 6-*striped male*: 24 antennal segments; eyes subnormal, small comparatively wider; abdominal segments 8. The main variation is seen in the elytron and wings, left elytron and wings normal, where as right elytron poorly developed and slender (23.80 mm.), right wing small and stumpy, hind legs broken; The values of sensitive characters C, P, E and ratio P/C lower than those in typical *gregaria*.For values of other characters and ratios *see* Table-3.

(i) 6-*striped male*: 26 antennal segments; eyes normal both length and width wise; abdominal segments 8; 13 (inner) and 13 (outer) tibial spines; tibial length 19.30 mm. The main variation is seen in the elytron and wings, left elytron and wing and right wing normal but right elytron very small (1.40 mm.) and stumpy. The values of sensitive characters C, P, E, F and ratio F/C lower than those in typical *gregaria* where as these are higher in respect to ratios P/C and E/F. For values of other characters and ratios *see* Table—3.

(j) 6-*striped male*: 26 antennal segments; eyes normal both length and width-wise; abdominal segments 8; 13 (inner) and 12 (outer) tibial spines; tibial length 18.75mm. The main variation is seen in the elytron and wings, right elytron and wings and left wing normal but left elytron poorly developed (13.40 mm). The values of sensitive characters C, P, E and F and ratios P/C, E/F and F/C are lower than those in typical *gregaria*. For values of other characters and ratios *see* Table-3.

(k) 6-*striped female*: 26 antennal segments; eyes normal; 12 (inner) and 13 (outer) tibial spines; tibial length 20.45 mm; on the inner side at the apical end of tibia 2 very small spines; the individual could not jump but crawl only. The main variation is seen in the elytron and wings, left elytron and wing and right wing normal but right elytron poorly developed (23.35 mm). The values of sensitive characters C, P, E and F and ratios P/C, E/F and F/C are lower than those in typical *gregaria*. For values of other characters and ratios *see* Table—3.

(l) 6-*striped female*: 23 antennal segments; eyes subnormal, comparatively wider; abdominal segments 8; hindlegs broken; the individual could crawl only. The main variation is seen in the elytron and wings, left and right elytron and right wing fully developed but crumpled, left wing less developed. The value of sensitive characters C. P and ratio P/C are lower than those in typical *gregaria*. For values of other characters and ratios *See* Table-3.

(C) Variations recorded in gregaria facies population in nature.

Bhanotar (1959) recorded asymmetry in the striped eyes of an individual (*coll.* 20.6.55) of 1955-Gr. II population in India, the last year

of 1949-55 locust cycle. With regard to morphometry and composition of eye stripes and sex ratios, the Gr. II was not significantly different from typical *gregaria*. This particular individual was obtained from a population density ranging 8500 per sq. mile. The morphometric characters indicated the *solitariform* features, however left eye had 7-stripes and the right 8-stripes.

III— Biological affinity of 7-striped and 6-striped (abnormal individuals obtained from crowded stock IARI—population)

(Tables 1, 3, 5 and 6)

For assessing the biological affinity of 7-striped and 6-striped (abnormal) individuals obtained from crowded stock (IARI-population) and for assigning them to phases, these were statistically tested ('t' test) with other known populations, available in literature as follows:

1. Typical phase gregaria (6-*greg.*) population (Roonwal, 1949; Roonwal and Nag, 1951).
2. Typical phase 6 and 7-*solitaria* population (Roonwal, 1949; Roonwal and Nag, 1951).
3. Ajmer swarm of 1950 (*Ajm. Sw.* (6) (Roonwal and Misra, 1952).
4. 1955-Gr. III (6-7-solitarious cum transitory) population (Roonwal and Bhanotar, 1966).

In the 7-striped category of IARI-population males, sample being too small (n=2), were not tested statistically. Inter-population comparison of various morphometric characters and ratios in respect of females are discussed as under:—

(A) 7-*striped individuals* (Tables 1 and 5)

(a) *Body characters*:

(I) *Width of head at genel level* (C) : *Females* : The value in IARI-population is significantly lower than that in 6-*greg.* and *Ajm. sw.* (6) at 5% level. However, it is not significantly different from that in 1955-Gr. III (6-7-) population. Comparison with 6-and 7 - striped individuals of *solitaria* was not possible due to lack of data.

(ii) *Length of pronotum* (P) : *Females*: The value in IARI-population is significantly lower than that in 6-*greg.* (at 1% level) and *Ajm. sw.* (6) at 5% level. It is also significantly lower than that in 1955-Gr. III (6) at 5% level and Gr. III (7) at 1% level. Comparison with 6-and 7 striped *solitaria* population was not possible due to lack of data.

(iii) *Height of pronotum* (H): *Females*: The value in IARI-pop. is significantly lower than that in 6-*greg.* at 1% level of probability.

Because of lack of data in 6-7-*sol.* and *Ajm. sw.* (6) populations, comparison was not possible.

TABLE 5.—Inter—population comparison between IARI—population (7-striped) and typical phase *gregaria, solitaria* (Roonwal, 1949; Roonwal and Nag, 1951). Ajmer swarm of 1950 (Roonwal and Misra, 1952) and 1955-Gr. III (Roonwal & Bhanotar 1966).

Abbreviations: As in table 1 and 3 and Ph. *sol.* (7), 7-striped individuals of phase *solitaria*; Ph. *greg* (6) or 6-*greg.*, 6-striped individuals of phase *gregaria*; *Ajm. sw.* (6), 6-striped individuals of Ajmer swarm of 1950; *, significant at 5% level; **, significant at 1% level, and N. S., Not significant.

Morphometric characters and ratios	Ph. *sol.* (7)	Ph. *greg* (6)	Ajm. sw. (6)	1955-Gr.III	
	♀ (7)	♀ (6)	♀ (6)	♀ (6)	♀ (7)
C	—	*	*	N. S.	N. S.
P	—	* *	* *	*	* *
H	—	* *	—	* *	* *
M	—	* *	—	* *	* *
E	* *	* *	—	* *	* *
F	* *	*	* *	* *	* *
E/F	* *	*	N. S.	N. S.	*
P/C	—	N. S.	N. S.	* *	* *
F/C	—	* *	N. S.	* *	* *
H/C	—	N. S.	—	* *	* *

(iv) *Width of pronotum at constriction* (M) : *Females*: The value in IARI-pop. is significantly lower than that in 6-*greg.* at 1% level. Comparison was not possible with 6-7-*sol.* and *Ajm. sw.* (6) due to lack of data.

(v) *Length of elytron* (E) : *Females*: The value in IARI-pop. is significantly lower than that in 6-*greg.* and 7-*sol.* at 1% level. No comparative data is available in case of *Ajm. sw.* (6).

(vi) *Length of hind-femur* (F): *Females*: The value in IARI-pop. is significantly lower than those in 6-*greg.* (at 5% level), 7-*sol.* and *Ajm. sw.* (6) at 1 % level.

(vii) *Restricted width of elytron* (W1): *Females*: The value in IARI-pop. is significantly lower than those in 1955-Gr. I(6), Gr. II (6) and Gr. III (7) at 1% level. No comparative data is available for other populations.

(b) *Ratios* :

(i) *Ratio E/F*: *Females*: The value in IARI-pop. is significantly lower than those in 6-*greg.* (at 5% level) and 7-*sol.* (at 1% level), where as it is not significantly different than that in *Ajm. sw.* (6).

(ii) *Ratio P/C* : *Females*: The value in IARI-pop. is not significantly different from those in 6-*greg.* and *Ajm. sw.* (6), but is significantly lower than that in 1955-Gr. III (7) at 1% level. No comparative data is available for 7-*sol.*

(iii) *Ratio F/C*: *Females*: The value in IARI-pop. is significantly higher than those in 6-*greg.* and 1955-Gr. III (7) at 1% level, but is not significantly different from that in *Ajm. sw* (6). No comparative data is available for 7-*sol.*

(iv) *Ratio H/C* : *Females*: The value in IARI-pop. is not significantly different from that in 6-*greg.*, but is significantly lower than that in 1955-Gr. III (7). No comparative data is available for other populations.

(B) 6-striped (abnormal) individuals

(Table—3 & 6)

(a) *Body characters* :

(i) *Width of head at genal level* (C) : *Males*: The value in IARI-pop, is significantly lower than those in 6-*greg.* and *Ajm. sw.* (6) at 1% level, but is not significantly different from that in 1955-Gr. III (6). *Females*: The value in IARI-pop. is significantly lower than those in 6-*greg.*, *Ajm. sw.* (6) and 1955—Gr. III (6) at 5% level.

(ii) *Length of pronotum* (P): *Males and Females*: The value in IARI-pop. is significantly lower than those in 6-*greg.* and 1955-Gr. III (6) at 1% level.

(iii) *Height of pronotum* (H) : *Males and Females*: The value in IARI-pop. is significantly lower than those in 6-*greg.* and 1955-Gr. III (6) at 1% level.

(iv) *Width of pronotum at constriction* (M): *Males and Females* : The value in IARI-pop. is significantly lower from those in 6-*greg.* (at 5% level) and 1955-Gr. III (6) at 1% level.

(v) *Length of elytron* (E): *Males*: The value in IARI-pop. is significantly lower from those in 6-*greg.* and 1955-Gr. III (6) at 1% level. *Females*: The value in IARI-pop. is not significantly different from those in 6-*greg.* and 1955-Gr. III (6).

(vi) *Length of hind femur* (F): *Males*: The value in IARI-pop. is significantly lower than that in 6-*greg.* (at 1% level) and 1955-Gr. III (6) at 5% level. *Females*: The value in IARI-pop. is significantly

lower than that in 1955-Gr. III (6) at 5% level, whereas it is not significantly different from that in 6-*greg*.

TABLE 6.—Inter-population Comparison between IARI—population (6-striped abnormal) and typical phase *gregaria*, *solitaria* (Roonwal, 1949; Roonwal and Nag, 1951), Ajmer swarm of 1950 Roonwal and Misra 1952) and 1955-Gr. III (Roonwal and Bhanotar, 1966).

Abbreviations:—As in table 1,3 and 5.

Morphometric characters and ratios	Ph.sol. (7)		Ph. *greg*. (6)		Ajm. sw. (6)		1955-Gr. III	
	♂	♀	♂	♀	♂	♀	♂ (6)	♀ (6)
C	—	—	* *	*	* *	*	N.S.	*
P	—	—	* *	* *	—	—	* *	* *
H	—	—	* *	* *	—	—	* *	* *
M	—	—	*	*	—	—	*	* *
E	* *	N. S.	* *	N. S.	—	—	* *	N. S.
F	* *	*	* *	N. S.	N. S.	*	*	*
P/C	—	—	N. S.	*	*	*	* *	* *
H/C	—	—	*	* *	—	—	* *	* *
E/F	N. S.	*	N. S.	*	N. S.	*	N. S.	*
F/C	—	—	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.

(b) *Ratios*:

(i) *Ratio E/F* : *Males*: The value in IARI-pop. is not significantly different from those in 6-*greg*. and 1955-Gr. III (6) at 5% level. *Females*: The value in IARI-pop. is significantly lower than those in 6 *greg*. and 1955-Gr. III (6) at 5% level.

(ii) *Ratio P/C*: *Males*: The value in IARI pop. is significantly lower than that in 1955 Gr. III (6) at 1% level, whereas it is not significantly different from that in 6 *greg*. *Females*: The value in IARI-pop. is significantly lower than those in 1955 Gr. III (6) at 1% level and 6 *greg*. (at 1% level).

(iii) *Ratio F/C*: *Males and Females*: The value in IARI-pop. is not significantly different from those in 1955-Gr. III (6) and 6-*greg*.

(iv) *Ratio H/C*: *Males and Females*: The value in IARI-pop. is significantly lower than those in 1955-Gr. III (6) and 6-*greg*. at 1% level, except at 5% level with 6-*greg*. males.

DISCUSSION

(1) Regarding the affinity to 7-striped individuals of IARI-population.

Of the important morphometric characters E, F, C, P, H and M for females, except for character 'C' which indicated the *solitaria* features

of the individuals, all other character show significant difference with both phase gregarious and solitarious cum transitory populations.

When compared with typical 7-striped *solitaria*, for which the data for three characters E, F and E/F is available, the IARI-pop. again revealed its significance difference from it at all levels of probability.

Of the other three ratios P/C, H/C and F/C, the former two (P/C and H/C) are in complete agreement with gregarious population *i.e.* they do not differ from each other in their values, where as between 7-striped females of 1955-Gr. III (7) the IARI-population indicates significant difference.

From the analysis we may conclude that 7-striped individuals obtained from crowded stock in laboratory as well as in nature creates imbalance in the stable gregarious population leading to weakening of the degree and intensity of gregarisation in swarming population eventually leading to disbursal and heralding the appearance of transitory individuals in nature thereby initiating the reversal shift towards phase transformation as happened in Dehra Dun swarm of 1954 (Roonwal, 1955).

This may also be one of the reasons that after every swarming season, 7-striped individuals are more frequently met in the wild field population after 3rd or 4th year of the swarming cycle.

It may be recalled here that basically 7-striped individuals make their appearance in nature during acute *solitaria* condition and these should be treated as such and related to phase *solitaria* and their appearance in gregarious populations, because of some other factors, merely creates disturbed equilibrium in the stable and constant characters normally associated with swarming phase.

(2) **Regarding the affinity of 6-striped (abnormal) individuals of IARI population.**

Of the characters E, F, C, P, H and M, the values in IARI population do not indicate any difference as far as character 'C' and ratio E/F is concerned when compared with 1955-Gr. III solitarious population whereas all other characters show significant difference.

In respect of females except for character E and ratio F/C, all other characters and ratios behave in the same way as in males. IARI-population when compared with typical *gregaria* values indicates significantly lower values in all characters in males except for ratios P/C, E/F and F/C and in females E, F and F/C.

Thus IARI-population of abnormal 6-striped individuals obtained from *gregaria* stock show less affinity to either phases and their appea-

rance after some generations in swarming population may create unstability in the constancy of swarming population.

The egg laying capacity of these females (abnormal) also dwindled considerably (36 eggs per pod).

CONCLUSIONS

The variations in the hitherto stable and consistant phase related to *gregaria* population has been observed in morphometric characters especially in the elytron, hindwings, antennal segments, tibial region and in the eye-stripes in Desert Locust. These variations are noticeable equally among males and females. The 7-striped forms so far related to phase *solitaria* also makes their appearance in gregarious population bred under crowded condition under normal laboratory condition after few generations. These 7-striped morphs behave in a typical gregarious way. So far few observations of such type have been recorded in nature. It is suggested that dynamics of swarming population in nature should be studied in detail as the occurrence of such variations may reveal the intensity and degree of gregarisation and probable hint towards start and decline of phase transformation.

ACKNOWLEDGEMENT

We are grateful to Dr. N. C. Pant, Head, Division of Entomology, IARI, New Delhi, for providing us necessary facilities.

REFERENCES

BHANOTAR, R. K. 1959. Asymmetry in striped eyes of the Desert Locust *Schistocerca gregaria* (Forskal).—*J. zool. Soc. India*, Calcutta, **10** (2) : 148-149.

BHANOTAR, R. K. *et al.*, 1972. facies and trend of Desert Locust population during 1971 in India. *Ent. Newsletter*, New Delhi, **2**(2) : 11-12.

BHANOTAR, R. K. and MAHTO, Y 1974. Variability in eye-stripes of Desert Locust from a *gregaria* egg. pod.—*Ent. Newsletter* New Delhi, **4** (8) : 43-44.

BHATIA, D. R. and SINGH, S. 1959. Occurrence of seven eye-striped individuals among phase gregaria adults of the Desert Locust (*Schistocerca gregaria* Forsk.).—*Indian J. Ent.*,—New Delhi, **21** (4) : 284-285.

CHAUVIN, R. 1941. Contribution a a'l'e tude physiologique du criquet pé lerin et du déterminisme des phénomènes grégaires. *Ann. Soc. Ent. Fr. Paris.* **110** : 133-272, 23 figs.

HUNTER-JONES, P. 1958. Laboratory studies on the inheritance of phase characters in Locust.-*Anti-Locust Bull.* London 29, **42** pp.

MAHTO, Y and BHANOTAR, R. K. The occurrence of 8-striped morph of the Desert Locust from laboratory bred crowded stock.—*Bombay Nat. Hist. Soc.* Bombay, MSS pp. 1-2 (in *Press*).

MISRA, S. D. 1952. Studies of eye stripe characteristics and biometrical ratios of the body parts in a concentration of Desert Locust individuals met with in July, 1949 in the Rajputana Desert, that brought about incipient swarming, and thus started a new locust cycle in India, pp. 100-122.—*Indian J. Ent.*, New Delhi, **14** (2) : 95-152.

MUKERJI, S. and BATRA, R. N. 1938. A note on the postembryonic development of eye-stripes and their correlation with the number of larval instars and the antennal segments in the life cycle of *Schistocerca gregaria* Forsk.—*5th Int. Locust Conf* Brussels: 410-416.

RAO, Y. RAMCHANDRA, 1960. *The Desert Locust in India. A monograph.* XIX+721 pp.—New Delhi (Indian Council of Agricultural Research, New Delhi).

ROONWAL, M. L. 1949. Studies in the intraspecific variation III. Body-size and biometrical ratios in various types of individuals of the Desert Locust *Schistocerca gregaria* (Forskal) (Orthoptera, Aceridídae).—*Rec. Indian Mus.*, Delhi, **45** (2-3) : 149-165.

ROONWAL, M. L. 1954. On a revolutionary phenomenon: The sharp increase of intraspecific variation in minimum population as evidenced by the Desert Locust.—*Rec. Indian Mus.*, New Delhi, **51** (4) : 481-525, 4 pls.

ROONWAL. M. L. 1955. Studies in intraspecific variation VII. Sex ratio and eye stripes in July, 1954 swarm (phase *gregaria*) of the Desert Locust, and a possible hint as to the decline of the current cycle.—*Indian J. Ent.*, New Delhi., **15** (1) : 6-10.

ROONWAL, M. L. 1958. Recent researches on population dynamics and evolutionary problem in the Desert Locust together with new theory of the visual maintenance of gregarisation in locusts.—*J. zool. Soc. India*, Calcutta, **9** (1) : 72-96, 1 pl.

ROONWAL, M. L. 1962. Phase and non-phase polymorphism in Desert Locust.—*Colleq. int. centre nation. Res. Sci. No.* 114 (*Physiol. Comport, Ecol. Acridiens rapport avec phase*), Paris, pp. 259 -263.

ROONWAL, M. L. and BHANOTAR, R. K. 1966 (*a*) Studies in intraspecific variation. Pt-XI. Morphological characters, sex-ratios and eye stripes in the 1955 population of Desert Locust in India.—*Rec. Indian Mus.*, New Delhi, **60** (1-2) : 1-80, 7 pls.

ROONWAL, M. L. and BHANOTAR, R. K. 1966 (*b*) Intraspecific variation. XII. Population dynamics and morphometry in Desert Locust in Calcutta swarm, January, 1961.—*Proc. 2nd. All India Cong. Zool.*, Varanasi, 1962, Part II, 287-296 pp., 1 pl., 3 tables.

ROONWAL, M. L. and MISRA, W D. 1952. Variability in a sample of Desert Locust population taken from a swarm in the Rajputana Desert, India, in 1950, the second year of a swarming cycle, together with discussion on the dynamics of phase transformation, pp. 112-126. In Misra, S. D., Nair K. R. and Roonwal, M. L. 1952.—*Indian J. Ent.*, New Delhi. **14** (2) : 95-152.

ROONWAL, M. L. and NAG, M. K. 1951. Studies in intraspecific variation. Part V Statistical supplement to the analysis of biometrical data on body size etc. of various types of individuals of the Desert Locust presented in Part III.—*Rec. Indian Mus.*, Delhi, **47** (3-4) (1949) : 265-275.

UVAROV, B. P. 1923. Notes on locusts of economic importance with some data on the periodicity of locust invasion.—*Bull. ent. Res.*, London, **14** (1) : 31-39.

UVAROV, B. P. 1928. *Locusts and grasshoppers. A hand book for their study and control.* 352, pp. several pls.—London (Imperial Institute Ent.).

UVAROV, B. P. 1966. *Grasshoppers and Locusts. A hand book of general Acridology.* Vol. I, pp. XI+1-481—London (Univ. Press Cambridge.)