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DEVELOPMENTAL PATHWAYS IN A FUNGUS GROWING TERMITE, *ODONTOTERMES OBESUS* (RAMBUR) (TERMITIDAE: MACROTERMITINAE)*

ABDUL SATTAR SHAHID AND MUHAMMAD SAEED AKHTAR

Department of Zoology, University of the Punjab, Quaid-e-Azam Campus (MSA), Lahore, Pakistan

Abstract: Developmental pathways of *O. obesus* based on the collection brought from the nest, were studied. It was found that workers in the colony were of two types (major workers and minor workers) differing only in minor details unlike those of the genus *Macrotermes*. However, after second instar larva they can be easily differentiated, as they have different mandibular size and shape (not pattern). Detailed studies on caste differentiation of a field colony of *O. obesus* revealed that major and minor workers develop from third instar larva. Both major and minor workers after their differentiation from third instar larva pass through three successive instars to become an adult sclerotized major or minor worker. There were many qualitative and quantitative changes from third instar larva to the adult workers. Biometrically all the instars of major workers and minor workers were significantly different in all the characters studied. However, for the total body length third instar major workers were not significantly different from adult workers. The origin of presoldier takes place from third instar minor worker larva. The presoldier after five significantly different instars develops into a soldier. It is in the last moult that rectangularly oval head characteristic of the species appears. The origin of alate line takes place from second instar larva. The nymph after five instars developed into alate. Biometrically all the instars were significantly different.

Key words: Developmental pathways, fungus, termite.

INTRODUCTION

Since the first publication by Grassi and Sandias nearly hundred years ago (1893-94) on caste determining mechanism in termites, this fascinating subject has attracted the attention of a large number of workers. Among the more important publications on the subject of caste differentiation are those of Miller (1942), Light (1944), Light and Weesner (1951), Luscher (1952, 1960, 1962, 1972, 1975, 1977), Buchli (1958), Lebrun (1967a,b), Springhetti (1970, 1971, 1973), Nagin (1972), Symthe and Mauldin (1972), Sewell and Watson (1981), Watson and Sewell (1981) and Noirot (1985a) on lower termites and those of Weesner (1953), Noirot (1955, 1956), Williams (1959a,b), Sands (1965a), Luscher (1976), Okot-Kotber (1981a,b, 1985) and Noirot (1985b) on higher termites.

Present Address: Welgreen Chemical (Pvt.) Ltd., 202-Latif Plaza, 103-Ferozepur Road, Lahore, Pakistan.
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In Pakistan, a detailed study on developmental pathways has been carried out by Afzal (1981) on the lower termite, *Bifiditermes beesoni* (Gardner). Some observations on caste differentiation in the fungus growing termite, *O. gurdaspurensis* have been made by Akhtar and Rana (1988).

The present study deals with the developmental lines of workers, soldiers and imagoes of *O. obesus* based on field colonies.

MATERIALS AND METHODS

The material used in the present study consisted of populations of subterranean nests of *O. obesus*. The population of the nest was separated by suspending the collection in water and was preserved in 80% alcohol. Measurements of different instars of worker, soldier and alate lines were taken with the calibrated ocular micrometer. Photographs of the various developmental stages were taken using an Olympus photomicroscope.

Taxonomic terms and measurements used in the present study are as explained by Emerson (1945) and Ahmad (1950).

To study the origin of major and minor worker developmental lines, following characters were measured.

Total body length.
Length of head to side base of mandibles.
Maximum width of head.
Length of hind tibia.

For the study of the developmental pathways of the soldier line, different larval instars were measured for the following characters:

Total body length.
Length of head to side base of mandibles.
Maximum width of head.
Length of left mandible.
Length of hind tibia.
Length of pronotum.
Width of pronotum.

For the study of the developmental pathways of the alate line following characters were studied:

Total body length.
Length of head to side base of mandibles.
Maximum width of head.
Length of hind tibia.
Length of wing pads.

Numerical data of various characters were analysed for mean ($\bar{x}$), standard deviation (S.D.) and co-efficient of variability (C.V.) according to Sokal and Rohlf (1969). For comparison of different instars, data were analysed by student "t" test.

RESULTS

Developmental line of major worker

On the basis of the statistical analysis of the measurements of the immature stages in the samples of field population of *O. obesus* it is inferred that the major worker passes through three larval instars followed by three successive instars of major workers (Fig.1).

The larval instar can be easily distinguished from the major worker instar as the larva is fragile and white due to absence of sclerotization (including the mandibles) and the gut appears empty and colourless. However, the workers contain gut content and appear coloured due to some pigmentation.

First instar larva

Head and body whitish, unpigmented, head nearly round; whitish brain mass visible through cuticle; head width 0.335-0.490 mm; brain occupying nearly the whole of head capsule. Mandibles unpigmented, whitish; left mandible with apical and first marginal tooth minutely indicated; right mandible with a slight indication of first marginal and apical tooth (Plate 1A). Antennae 12-segmented, transparent; first and second segments distinct, nearly equal. Antennal portion near third and fourth segment not clearly segmented; segmentation distinct beyond fourth segment. Abdomen with a pair of styli. Tarsi indistinctly 4-segmented (Table I).

Table I: Biometric analysis of different characters of first instar larva of *O. obesus* (measurements are in mm)

Character	Range (n-25)	Mean±S.D.	C.V.
Total body length	0.8450-1.729	1.346±0.201	14.911
Length of head to side base of mandibles	0.258-0.335	0.294±0.021	7.065
Width of head	0.335-0.490	0.429±0.031	7.321
Length of hind tibia	0.181-0.232	0.192±0.014	7.392

Second instar larva

Head and body whitish; unpigmented. Head nearly round; brain area visible through cuticle, large occupying 75% of the whole head capsule. Mandibles

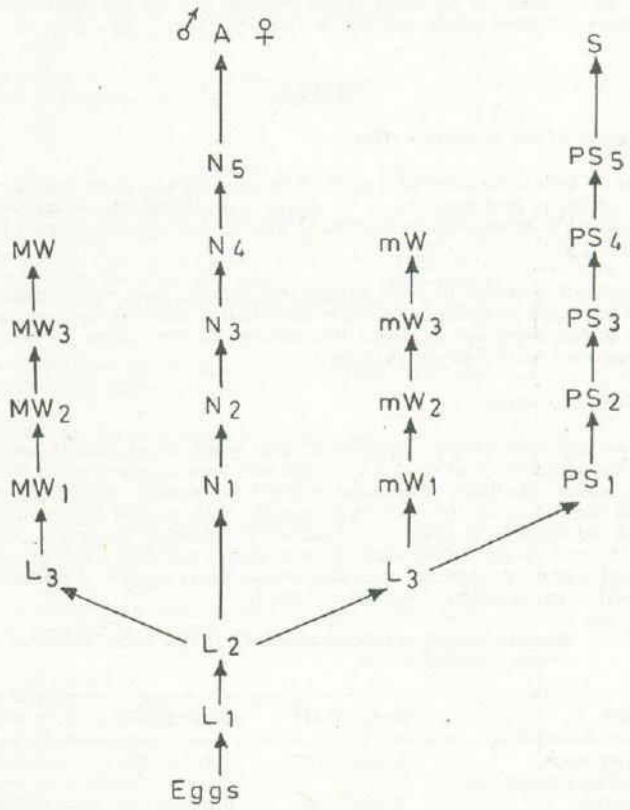

Fig. 1: A scheme of post-embryonic development in a mature field colony of *O. obesus*. L_1-L_3, larval instars 1-3; MW_1-MW_3, major worker instars 1-3; MW, major worker; mW_1-mW_3, minor worker instars 1-3; mW, minor worker; PS_1-PS_5, pre-soldier instars 1-5; S, soldier; N_1-N_5, nymphal instars 1-5; A, alate.

mature field colony of *O.*
ajor worker instars 1-3; MW,
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Ns, nymphal instars 1-5; A,

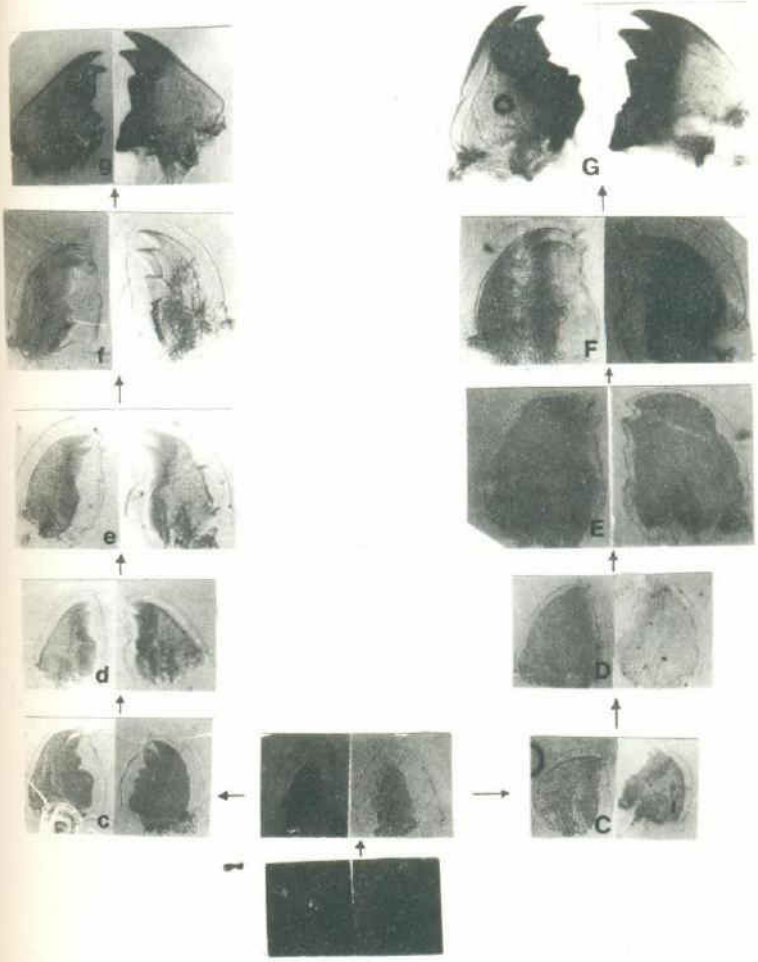

Plate 1: Stages of mandibular development of major and minor workers of O. obesus. A, first stage larva; B, second stage larva; C, third stage larva of major workers; c, third stage larva of minor workers; D,E,F, major worker instars 1-3; d,e,f, minor worker instars 1-3; G, major worker; g, minor worker. Magnification; A,B,c = X200; C-G and d-g = X100.

unpigmented; inner mandibular side dirty white; rest of the area transparent. Pigmentation not started yet; right mandible with apical and first marginal tooth slightly more developed than first instar larvae; notch between first and second marginal tooth slightly indicated; left mandible with first marginal and apical tooth distinct; notch between first and second marginal in initial stage of development; slightly indicated (Plate 1B). Antennae with 13 articles. Abdomen with a pair of styli. Tarsi 4-segmented (Table II).

Table II: Biometric analysis of different characters of second instar larva of *O. obesus* (measurements are in mm)

Character	Range (n=25)	Mean±S.D.	C.V.
Total body length	1.73-2.296	1.986±0.154	7.744
Length of head to side base of mandibles	0.361-0.387	0.382±0.009	2.380
Width of head	0.542-0.619	0.577±0.0004	3.328
Length of hind tibia	0.335-0.387	0.336±0.015	4.211

Third instar larva

Head and body dirty white, unpigmented. Head nearly round; brain not visible through cuticle. Mandibles more differentiated than second instar larvae; all the teeth have developed and visible under the old cuticle; apical and first marginal with a slight brownish tinge; right mandible with a distinct notch between first and second marginal tooth; second notch between posterior margin of second marginal tooth and molar plate slightly indicated. Left mandible also with a distinct notch between first marginal and second marginal tooth; second notch between second marginal and molar plate also slightly indicated, unpigmented (Plate 1C). Antennae with 14 articles. Abdomen with a pair of styli. Tarsi 4-segmented (Table III).

Table III: Biometric analysis of different characters of third instar larva of *O. obesus* (measurements are in mm)

Character	Range (n=25)	Mean±S.D.	C.V.
Total body length	2.477-3.122	2.847±0.156	5.494
Length of head to side base of mandibles	0.490-0.568	0.521±0.024	4.547
Width of head	0.645-0.748	0.708±0.029	4.954
Length of hind tibia	0.439-0.490	0.450±0.015	3.267

First instar major worker

The first instar major worker develops from third instar larva. Head and body slightly brownish yellow; brain area visible through cuticle; head brain index 0.6; mandibles more differentiated than third instar larva; teeth slightly pigmented in some

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est of the area transparent. nd first marginal tooth slightly irst and second marginal tooth d apical tooth distinct; notch levelopment; slightly indicated air of styli. Tarsi 4-segmented

second instar larva of *O. obesus*

lean±S.D.	C.V.
986±0.154	7.744
382±0.009	2.380
577±0.0004	3.328
336±0.015	4.211

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of third instar larva of *O. obesus*

Mean±S.D.	C.V.
.847±0.156	5.494
,521±0.024	4.547
.708±0.029	4.954
.450±0.015	3.267

ird instar larva. Head and body cuticle; head brain index 0.6; teeth slightly pigmented in some

specimens; left mandible with outer cuticle provided with distinct apical and first plus second marginal; posterior end of the first and second marginal tooth convex; developing mandible within the cuticle with distinct apical, first plus second marginal and with an indication of a notch between first plus second and third marginals (Plate 1D). Antennae with 15 articles. Abdomen with a pair of styli. Tarsi 4-segmented (Table IV).

Table IV: Biometric analysis of different characters of first instar major worker (measurements are in mm).

Character	Range (n=25)	Mean±S.D.	C.V.
Total body length	2.709-3.612	3.288±0.232	7.056
Length of head to side base of mandibles	0.542-0.619	0.569±0.023	3.991
Width of head	0.722-0.851	0.771±0.033	4.234
Length of hind tibia	0.593-0.722	0.660±0.030	4.549

Second instar major worker

Head and thorax slightly darker than the abdomen; head oval narrowing posteriorly; brain clearly visible through cuticle; brain smaller in proportion to head than in earlier stages; mandibles at tips more pigmented than first instar major worker; left mandible almost like that of first instar major worker; right mandible with old cuticle indicating first and second marginals; notch between third marginal and molar plate present; developing mandible within old cuticle with distinct apical, first and second marginals but with regressed third marginal tooth; notch also not distinct (Plate 1E). Antennae with 16 articles; dirty white. Abdomen with a pair of styli. Tarsi 4-segmented (Table V).

Table V: Biometric analysis of different characters of second instar major worker (measurements are in mm).

Character	Range (n=25)	Mean±S.D.	C.V.
Total body length	3.612-4.076	3.885±0.021	3.686
Length of head to side base of mandibles	0.774-0.851	0.820±0.026	3.160
Width of head	1.032-1.187	1.125±0.039	3.494
Length of hind tibia	0.774-0.877	0.825±0.024	2.898

Third instar major worker

Head yellowish brown, much darker, oval. Brain clearly visible through cuticle. Mandibles sclerotized, brownish red; left mandible with distinct apical, first and second marginal teeth; posterior margin of first and second marginal teeth and anterior margin of third marginal making a notch, which at this stage is well indicated, deep (Plate 1F).

Antennae with 17 articles; distal articles darker than proximal; distal articles yellowish brown; first antennal article as long as third and fourth combined. Abdomen with a pair of styli. Tarsi 4-segmented (Table VI).

Table VI: **Biometric analysis of different characters of third instar major worker (measurements are in mm).**

Character	Range (n=10)	Mean±S.D.	C.V.
Total body length	4.386-4.902	4.670±0.155	3.328
Length of head to side base of mandibles	0.851-0.929	0.880±0.029	3.251
Width of head	1.161-1.238	1.215±0.026	2.098
Length of hind tibia	0.851-0.903	0.872±0.024	2.741

Major worker

Like third instar major worker except that head much brownish and darker; brain much smaller as compared to head size. Mandibles strongly sclerotized (Plate 1G; Table VII).

Table VII: **Biometric analysis of different characters of major worker of *O. obesus* (measurements are in mm).**

Character	Range (n=25)	Mean±S.D.	C.V.
Total body length	4.386-5.031	4.736±0.162	3.429
Length of head to side base of mandibles	1.032-1.445	1.297±0.095	7.339
Width of head	1.393-1.625	1.529±0.069	4.525
Length of hind tibia	0.980-1.238	1.138±0.075	6.626

Comparison of different instars of major workers of O. obesus

Total body length

The range, mean and standard deviation of total body length of different instars of major worker line are given in Table VIII. Frequency distribution of total body length of different instars is illustrated in Fig.2. The co-efficient of variability was maximum for first instar larva, whereas it was minimum for third instar major worker indicating that the growth has completed and the specimens are therefore relatively less variable. Comparison of different instars of major worker line of *O. obesus* was carried out by student "t" test, which revealed significant differences ($P<0.05$) between all the

Fig. 2: Frequency distribution of total body length in different instars of major worker line of *O. obesus*.

TOTAL BODY LENGTH (mm)
(GROUP INTERVAL = 0·1 mm)

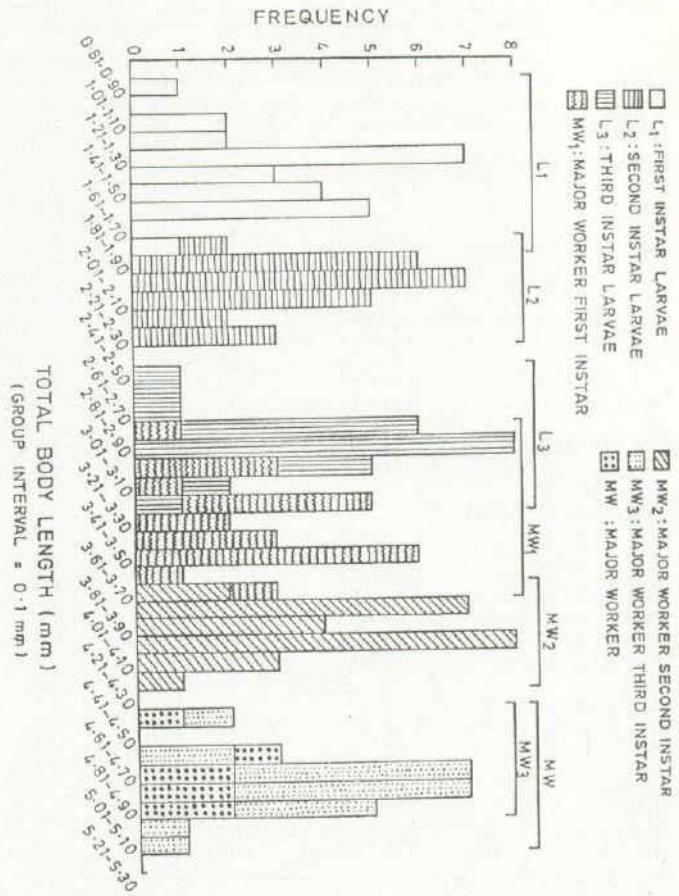

FIG. 2. Frequency distribution of total body length in different instars of major worker line of *O. obesus*.

instars. However, third instar major worker and adult major worker were not significantly different ($P>0.05$) for total body length (Table VIII).

Table VIII: Age variation in different instars of major worker of *O. obesus* (vertical lines alongside the instars indicate non-significant differences; $P>0.05$).

Instar	Range (n=25)	Mean±S.D.	C.V.
Total body length			
L_1	0.85-1.73	1.35±0.201	14.91
L_2	1.70-2.30	1.99±0.154	7.74
L_3	2.48-3.12	2.85±0.156	5.49
MW_1	2.71-3.61	3.29±0.232	7.07
MW_2	3.61-4.08	3.89±0.021	3.69
MW_3	4.39-4.90	4.67±0.155	3.33
MW	4.39-5.03	4.74±0.162	3.43
Length of head to side base of mandibles			
L_1	0.26-0.34	0.29±0.021	7.07
L_2	0.36-0.39	0.38±0.009	2.38
L_3	0.49-0.57	0.52±0.024	4.55
MW_1	0.54-0.62	0.57±0.023	3.99
MW_2	0.77-0.85	0.82±0.026	3.16
MW_3 (n=10)	0.85-0.93	0.88±0.029	3.25
MW	1.03-1.45	1.30±0.095	7.34
Maximum width of head			
L_1	0.34-0.49	0.43±0.031	7.32
L_2	0.54-0.62	0.58±0.004	3.33
L_3	0.65-0.75	0.71±0.029	4.05
MW_1	0.72-0.85	0.77±0.33	4.23
MW_2	1.03-1.19	1.13±0.039	3.49
MW_3 (n=10)	1.16-1.24	1.22±0.026	2.10
MW	1.39-1.63	1.53±0.069	4.53
Length of hind tibia			
L_1	0.18-0.23	0.19±0.014	7.39
L_2	0.34-0.39	0.37±0.015	4.21
L_3	0.44-0.49	0.45±0.015	3.27
MW_1	0.59-0.72	0.66±0.030	4.55
MW_2	0.77-0.88	0.83±0.024	2.90
MW_3 (n-10)	0.85-0.90	0.87±0.024	2.74
MW	0.98-1.24	1.14±0.075	6.63

Length of head to side base of mandibles

The range, mean and standard deviation of length of head to side base of mandibles for different instars of major worker line are given in Table VIII. Frequency distribution of various instars of major workers of *O. obesus* for length of head to side base of mandibles is illustrated in Fig.3.

Fig. 3: Frequency distribution of length of head to side base of mandible in different instars of major worker line of *O. obesus*.

LENGTH OF HEAD TO SIDE BASE OF MANDIBLES
(GROUP INTERVAL = 0·03 mm)

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lt major worker were not
le VIII).

ker of *O. obesus* (vertical lines
fferences: P>0.05).

S.D.	C.V.
291	14.91
154	7.74
156	5.49
232	7.07
021	3.69
155	3.33
162	3.43
021	7.07
009	2.38
024	4.55
023	3.99
026	3.16
029	3.25
095	7.34
031	7.32
004	3.33
029	4.05
33	4.23
039	3.49
026	2.10
069	4.53
014	7.39
015	4.21
015	3.27
030	4.55
024	2.90
024	2.74
075	6.63

of head to side base of mandibles
Table VIII. Frequency distribution
of length of head to side base of

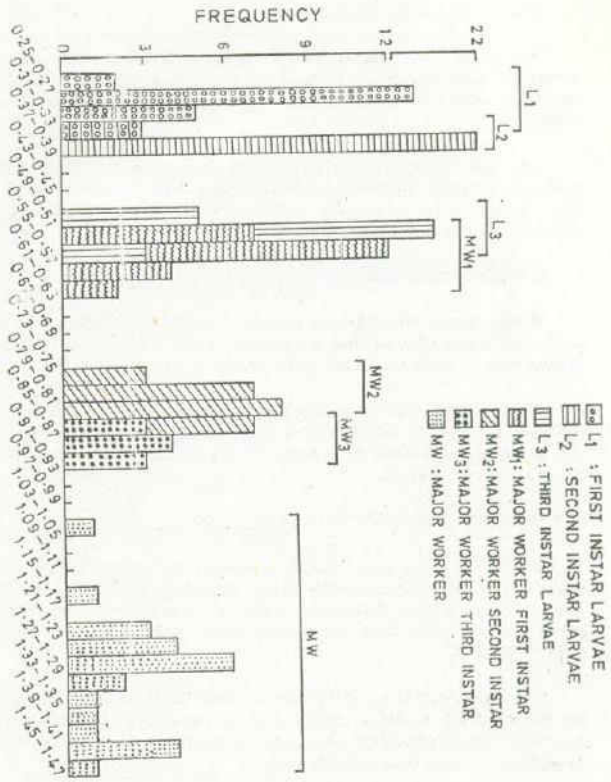

Fig. 5: Frequency distribution of length of head to side base of mandible in different instars of major worker line of *O. obesus*.

The co-efficient of variability was maximum for adult major workers, whereas, it was minimum for second instar larva of *O. obesus* (Table VIII). Comparison of different instars of major workers of *O. obesus* for maximum width of head revealed significant differences ($P<0.05$) in all the instars studied.

Maximum width of head

The range, mean and standard deviation of different instars of major workers of *O. obesus* for maximum width of head are given in Table VIII. Frequency distribution of maximum width of head of different instars of major workers of *O. obesus* is illustrated in Fig.4.

The co-efficient of variability was maximum for first instar larva, whereas, minimum for third instar major worker (Table VIII). Comparison of different instars of major workers of *O. obesus* for maximum width of head revealed significant differences ($P<0.05$) in all the instars studied.

Length of hind tibia

Range, mean and standard deviation of different instars of major workers of *O. obesus* for length of hind tibia are given in Table VIII. Frequency distribution of length of hind tibia of different instars of *O. obesus* is also illustrated in Fig.5.

The co-efficient of variability was maximum for first instar larva and was minimum for third instar major worker (Table VIII). Comparison of different instars of *O. obesus* (for length of hind tibia) by student "t" test revealed significant differences ($P<0.05$) between different instars.

Developmental line of minor worker

Like the major worker, the minor worker also passes through three larval and three successive minor worker instars before becoming adult (Fig.1). The first two larval instar of major worker and minor worker are common, but the third larval instar of the minor worker differ from the corresponding stage in the development of the major worker (Plate 1C).

The third stage larva of the minor worker differ from that of the third stage larva of the major worker in overall structure of the mandibles. The minor worker larva possess relatively anteroposteriorly elongated mandibles, whereas in major worker larva, mandibles are more robust and broader.

Third instar larva

Head and body whitish; unpigmented, head round. Mandibles unpigmented, left mandible with indications of apical and first marginal teeth; right mandible also with indication of apical and first marginal teeth (Plate 1C). Antennae with 13-14 articles, whitish, first and second article larger than others, second article nearly twice as long as third. Abdomen unpigmented and have a pair of styli. Tarsi 4-segmented (Table IX).

Fig. 4. Frequency distribution of maximum width of head in different instars of major worker line of *O. obesus*.

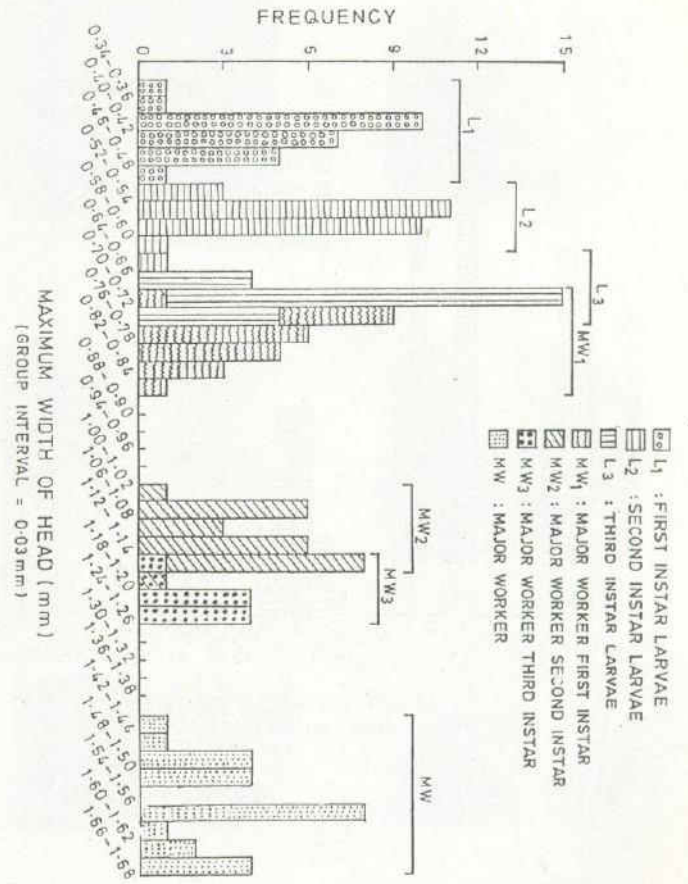

Fig. 4: Frequency distribution of maximum width of head in different instars of major worker line of *O. obesus*.

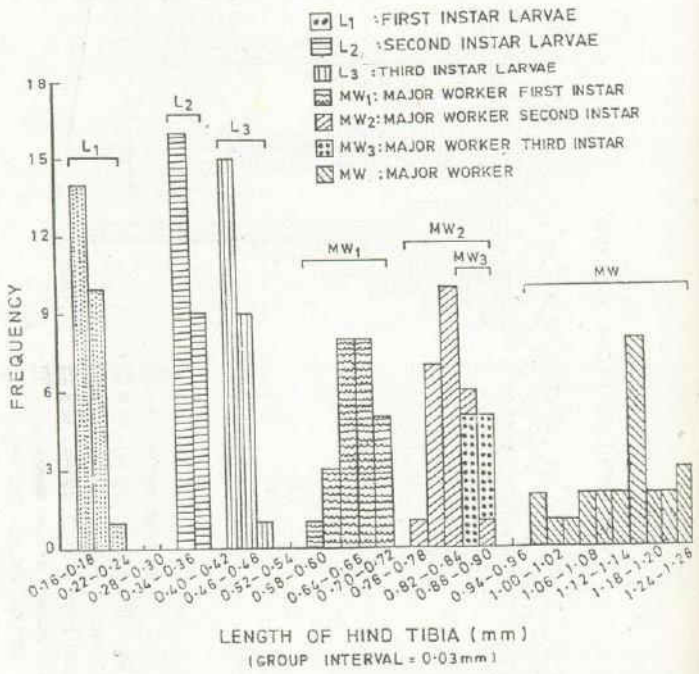

Fig. 5: Frequency distribution of length of hind tibia in different instars of major worker line of *O. obesus*.

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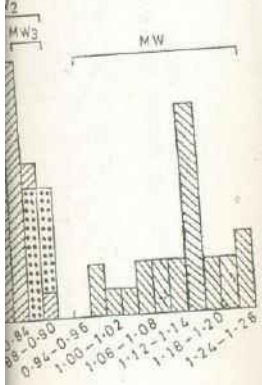
STAR LARVAE
INSTAR LARVAE
TAR LARVAE
ORKER FIRST INSTAR
ORKER SECOND INSTAR
ORKER THIRD INSTAR
VORKER



BIA (mm)
1-03mm)

of hind tibia in different instars of major

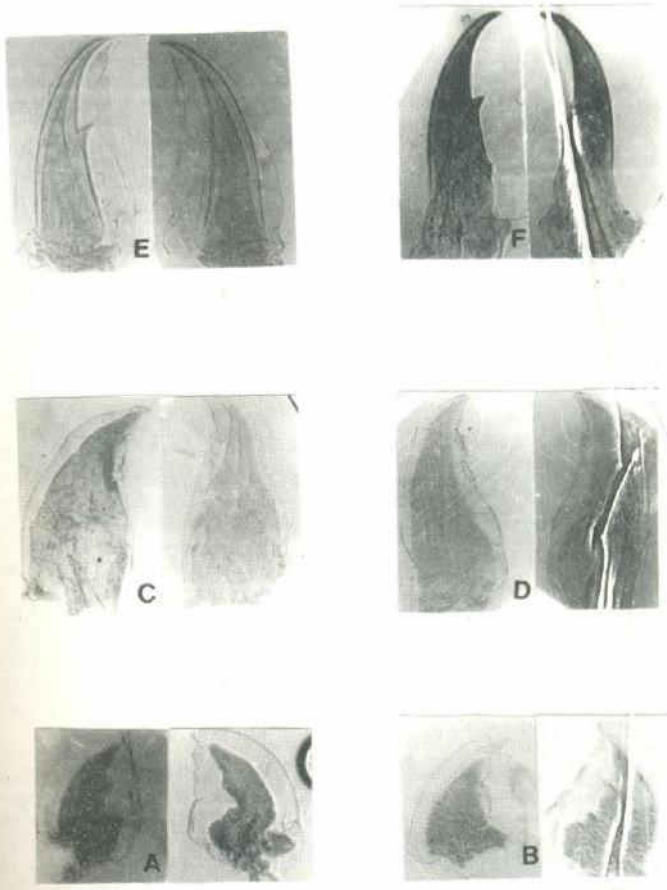


Plate II: Stages of mandibular development during soldier differentiation. A, first instar pre-soldier; B, second instar pre-soldier; C, third instar pre-soldier; D, fourth instar pre-soldier; E, fifth instar pre-soldier; F, mature soldier. Magnification: X100.

First instar minor worker

Head slightly darker than abdomen; head round; brain not clearly visible through cuticle. Mandibles whitish; unpigmented; right mandible with apical and first marginal more developed than third instar larva, left mandible first marginal and second marginal teeth differentiating within old cuticle (Plate 1D). Antennae with 14 articles. Abdomen with a pair of styli. Tarsi 4-segmented (Table X).

Table IX: **Biometric analysis of different characters of third instar larva of *O. obesus* (measurements are in mm).**

Character	Range (n=10)	Mean±S.D.	C.V.
Total body length	2.19-2.65	2.37±0.14	6.02
Length of head to side base of mandibles	0.39-0.44	0.41±0.018	4.32
Width of head	0.57-0.67	0.62±0.67	4.60
Length of hind tibia	0.36-0.41	0.38±0.015	3.85

Table X: **Biometric analysis of different characters of first instar minor worker of *O. obesus* (measurements are in mm).**

Character	Range (n=10)	Mean±S.D.	C.V.
Total body length	2.84-3.10	2.96±0.097	3.26
Length of head to side base of mandibles	0.46-0.57	0.52±0.030	5.81
Width of head	0.72-0.80	0.74±0.025	3.40
Length of hind tibia	0.44-0.46	0.45±0.013	2.87

Second instar minor worker

Head slightly darker than the abdomen; weakly sclerotized. Head nearly rounded; brain area visible through cuticle, nearly occupying whole of the head capsule. Mandibles more differentiated than the first instar minor worker; teeth slightly pigmented; left mandible with notch between first and second marginal teeth slightly indicated, second notch between posterior margin of second marginal and molar plate indistinctly indicated; tips of teeth slightly pigmented (Plate 1E). Antennae with 15 articles. Abdomen with a pair of styli. Tarsi 4-segmented (Table XI).

Third instar minor worker

Head and thorax more darker than the second instar minor worker; weakly sclerotized. Head round; brain clearly visible through cuticle, occupies 50% area of the head capsule. Mandibles more darkly pigmented than second instar minor worker; teeth completely differentiated (Plate 1F). Antennae with 16 articles. Abdomen weakly sclerotized, a pair of styli present. Tarsi 4-segmented (Table XII).

Table XI: Biometric analysis of different characters of first second minor worker of *O. obesus* (measurements are in mm).

Character	Range (n=10)	Mean±S.D.	C.V.
Total body length	3.15-3.61	3.41±0.130	3.83
Length of head to side base of mandibles	0.57-0.62	0.58±0.018	3.04
Width of head	0.77-0.83	0.79±0.018	2.30
Length of hind tibia	0.67-0.70	0.68±0.014	2.00

Table XII: Biometric analysis of different characters of third instar minor worker of *O. obesus* (measurements are in mm).

Character	Range (n=10)	Mean±S.D.	C.V.
Total body length	3.61-3.82	3.70±0.066	1.80
Length of head to side base of mandibles	0.62-0.67	0.64±0.018	2.75
Width of head	0.85-0.93	0.89±0.022	2.47
Length of hind tibia	0.70-0.75	0.72±0.021	2.88

Minor worker

Head brownish, much darker than third instar minor worker. Head oval; brain clearly visible, appearing smaller in comparison to size of the head capsule. Mandibles much sclerotized with well differentiated notches and fully developed teeth (Plate 1G). Antennae with 17 articles, first and second antennal articles much larger than others. Abdomen with a pair of styli. Tarsi 4-segmented (Table XIII).

Table XIII: Biometric analysis of different characters of minor worker of *O. obesus* (measurements are in mm).

Character	Range (n=10)	Mean±S.D.	C.V.
Total body length	3.74-4.00	3.87±0.081	2.09
Length of head to side base of mandibles	0.77-0.85	0.81±0.022	2.68
Width of head	0.96-1.08	1.01±0.041	4.03
Length of hind tibia	0.93-0.96	0.94±0.013	1.35

Comparison of different instars of minor worker of O. obesus

Total body length

Range, mean and standard deviation of different instars of minor worker of *O. obesus* for total body length are given in Table XIV.

Table XIV: **Age variation in different parameters in measurement of different instars of minor worker of *O. obesus* (vertical lines alongside the instars indicate non-significant differences; P > 0.05).**

Instar	Range (n = 10)	Mean ± S.D.	C.V.
Total body length			
L_1	2.19-2.63	2.37 ± 0.143	6.02
mW_1	2.84-3.10	2.96 ± 0.097	3.26
mW_2	3.15-3.61	3.41 ± 0.130	3.83
mW_3	3.61-3.82	3.70 ± 0.066	1.80
mW	3.74-4.00	3.87 ± 0.081	2.09
Length of head to side base of mandibles			
L_3	0.39-0.44	0.41 ± 0.018	4.32
mW_1	0.46-0.57	0.52 ± 0.030	5.81
mW_2	0.57-0.62	0.58 ± 0.018	3.04
mW_3	0.62-0.67	0.64 ± 0.018	2.75
mW	0.77-0.85	0.81 ± 0.022	2.68
Maximum width of head			
L_3	0.57-0.67	0.62 ± 0.028	4.60
mW_1	0.72-0.80	0.74 ± 0.025	3.40
mW_2	0.77-0.83	0.79 ± 0.018	2.30
mW_3	0.85-0.93	0.89 ± 0.022	2.47
mW	0.96-1.08	1.01 ± 0.041	4.03
Length of hind tibia			
L_3	0.36-0.41	0.38 ± 0.015	3.85
mW_1	0.44-0.46	0.45 ± 0.013	2.87
mW_2	0.67-0.70	0.68 ± 0.014	2.00
mW_3	0.70-0.75	0.72 ± 0.021	2.88
mW	0.93-0.96	0.94 ± 0.013	1.35

Frequency distribution of different instars of minor worker of *O. obesus* for total body length is illustrated in Fig.6.

The co-efficient of variability was 6.02, 3.26, 3.83, 1.80 and 2.09 for third instar larva, first instar, second instar, third instar minor workers and adult minor workers, respectively (Table XIV).

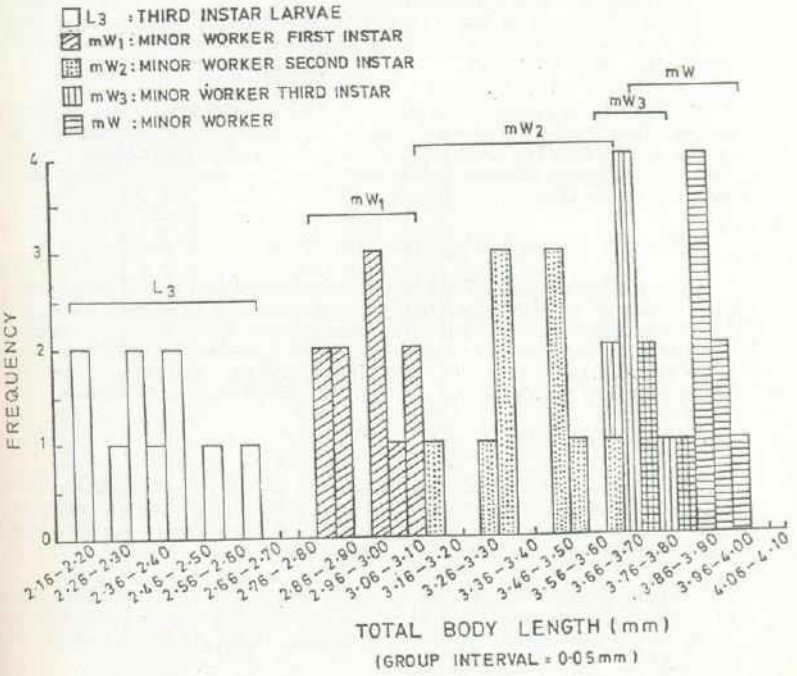


Fig. 6: Frequency distribution of total body length in different instars of minor worker line of *O. obesus*.

Comparison of different instars by student "t" test revealed significant differences ($P<0.05$) between all the instars of *O. obesus* for total body length.

Length of head to side base of mandibles

For length of head to side base of mandibles, different instars of minor worker of *O. obesus* ranged between 0.39 mm - 0.85 mm (Table XIV). Range, mean and standard deviation of each instar are also given in Table XIV. Frequency distribution of various instars of minor workers of *O. obesus* for length of head to side base of mandibles is illustrated in Fig.7.

Co-efficient of variability was maximum (5.81) for first instar minor worker and was minimum (2.68) for adult minor worker. Comparison of different instars of minor worker of *O. obesus* by student "t" test revealed significant differences ($P<0.05$) between all the instars of minor workers of *O. obesus* for length of head to side base of mandibles (Table XIV).

Maximum width of head

Range, mean and standard deviation of maximum width of head of minor workers of *O. obesus* are given in Table XIV. Frequency distribution of different instars of *O. obesus* for maximum width of head is illustrated in Fig.8. The co-efficient of variability was maximum (4.60) for third instar larva, whereas, it was minimum (2.30) for second instar minor worker of *O. obesus* (Table XIV). Comparison of different instars of *O. obesus* for maximum width of head revealed significant differences ($P<0.05$).

Length of hind tibia

Range, mean and standard deviation of length of hind tibia of different instars of minor worker of *O. obesus* are given in Table XIV. The co-efficient of variability of minor workers of *O. obesus* for length of hind tibia was maximum for third instar larva and was minimum for adult minor worker (Table XIV).

Frequency distribution of length of hind tibia of various instars of minor workers of *O. obesus* is illustrated in Fig.9. Different instars of minor workers of *O. obesus* for length of hind tibia were significantly different ($P<0.05$) by student "t" test (Table XIV).

Developmental line of soldier

The statistical data pertaining to immature stages in a field colony of *O. obesus* reveal that the third stage larva from which arises the developmental line of minor worker, also give rise to soldier line. The pre-soldier arising from the third instar larva

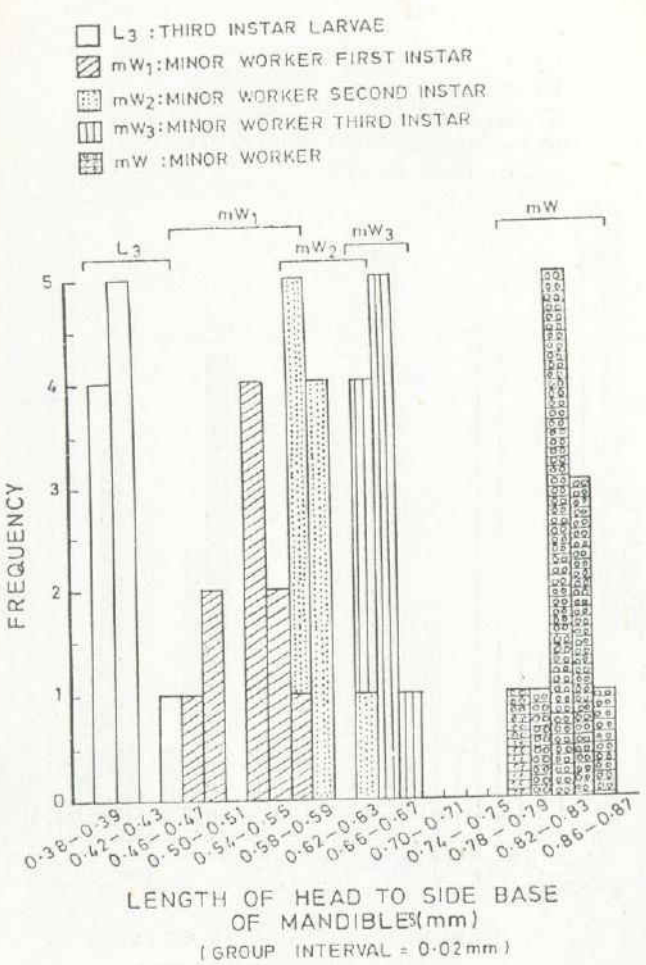


Fig. 7: **Frequency distribution of length of head to sidebase of mandibles in different instars of minor workers line of *O. obesus*.**

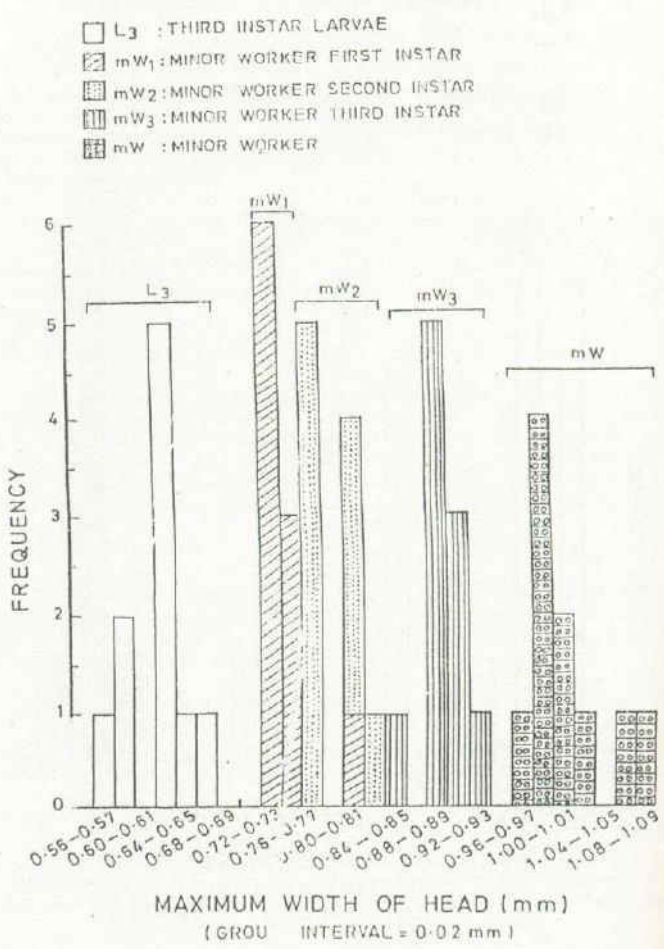


Fig. 8: Frequency distribution of maximum width of head in instars of minor worker line of *O. obesus*.

Fig. 9:

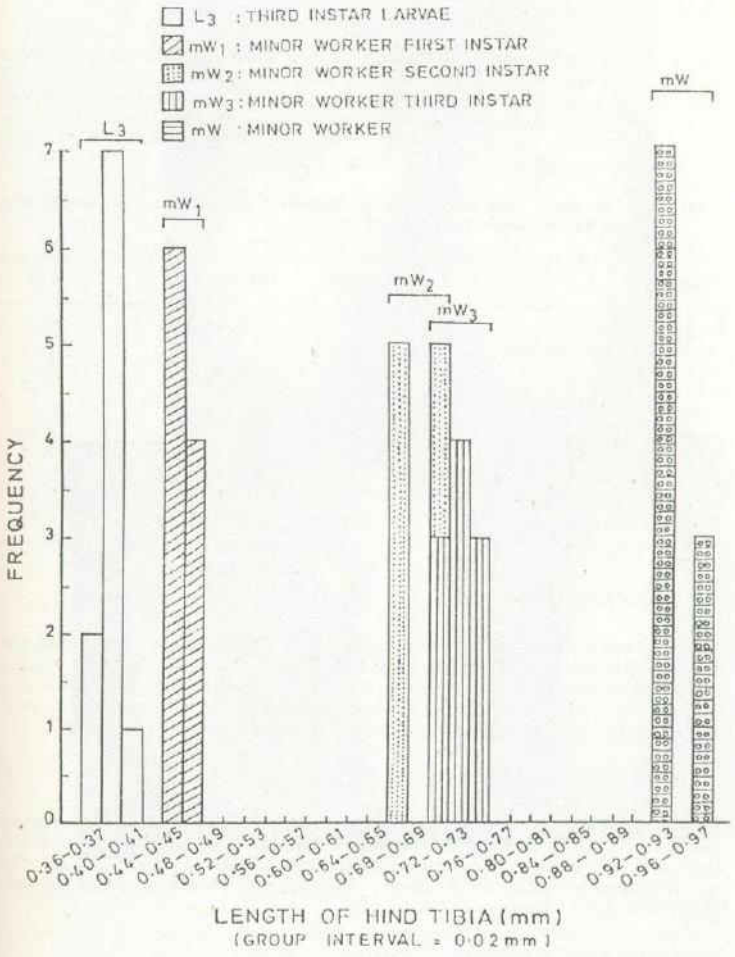
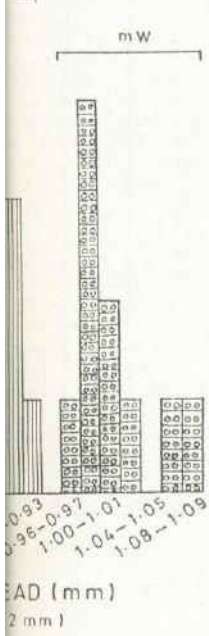


Fig. 9: **Frequency distribution of length of hind tibia different in instars of minor worker of *O. obesus*.**



head in instars of minor worker

moults for five times before becoming adult (Fig.1). The various stages of development of the soldier are described below in detail.

First instar pre-soldier

Head and body whitish, head nearly round. Mandibles showing indication of soldier development within the mandibles of third instar larva of minor worker. Left mandible with apical tooth clearly visible within the older intact cuticle of third instar larva, mandibular tooth slightly indicated; right mandible with apical and first marginal tooth developed like the left mandible (Plate 2A). Antennae with 14-15 articles, abdomen with a pair of styli. Tarsi 4-segmented (Table XV).

Table XV: **Biometric analysis of different characters of first instar pre-soldier of *O. obesus* (measurements are in mm).**

Character	Range (n=25)	Mean±S.D.	C.V.
Total body length	3.15-3.61	3.37±0.136	4.04
Length of head to side base of mandibles	0.54-0.64	0.60±0.031	5.10
Maximum width of head	0.75-0.83	0.78±0.021	2.67
Length of left mandible	0.36-0.44	0.41±0.024	5.74
Length of hind tibia	0.67-0.73	0.70±0.018	2.56
Length of pronotum	0.21-0.31	0.26±0.025	9.65
Width of pronotum	0.46-0.54	0.50±0.024	4.73
Length of brain (n=20)	0.26-0.36	0.32±0.030	9.37
Width of brain (n=20)	0.49-0.65	0.56±0.039	6.98

Second instar pre-soldier

Head and abdomen whitish; head nearly round. Mandibles with apical tooth more elongated than the first instar pre-soldier, tips slightly pigmented. The older cuticle of the third instar larva of the minor worker still persist; first marginal tooth of third instar larva of minor worker still not completely absorbed (Plate 2B). Antennae with 15 articles. Abdomen with a pair of styli. Tarsi 4-segmented (Table XVI).

Third instar pre-soldier

Head and abdomen whitish, head nearly oval. Mandibles whitish, more elongated than second instar pre-soldier; first marginal tooth of third instar minor worker larva much absorbed; sclerotization not started yet, inner margin of mandibles wavy (Plate 2C). Brain clearly visible, much reduced. Antennae with 16 articles. Abdomen with a pair of styli. Tarsi 4-segmented (Table XVII).

Fourth instar pre-soldier

Head oval, slightly pigmented, dirty white; mandibles brownish yellow, well differentiated; left mandible with distinct tooth, right mandible with slight indication of tooth (Plate 2D). Brain visible, much reduced as compare to head capsule. Abdomen not

he various stages of development

Mandibles showing indication of
star larva of minor worker. Left
older intact cuticle of third instar
ble with apical and first marginal
Antennae with 14-15 articles.
XV).

s of first instar pre-soldier of *O.*

Mean±S.D.	C.V.
3.37±0.136	4.04
0.60±0.031	5.10
0.78±0.021	2.67
0.41±0.024	5.74
0.70±0.018	2.56
0.26±0.025	9.65
0.50±0.024	4.73
0.32±0.030	9.37
0.56±0.039	6.98

Mandibles with apical tooth more
y pigmented. The older cuticle of
first marginal tooth of third instar
d (Plate 2B). Antennae with 15
ted (Table XVI).

Mandibles whitish, more elongated
f third instar minor worker larva
margin of mandibles wavy (Plate
with 16 articles. Abdomen with a

mandibles brownish yellow, well
mandible with slight indication of
pare to head capsule. Abdomen not

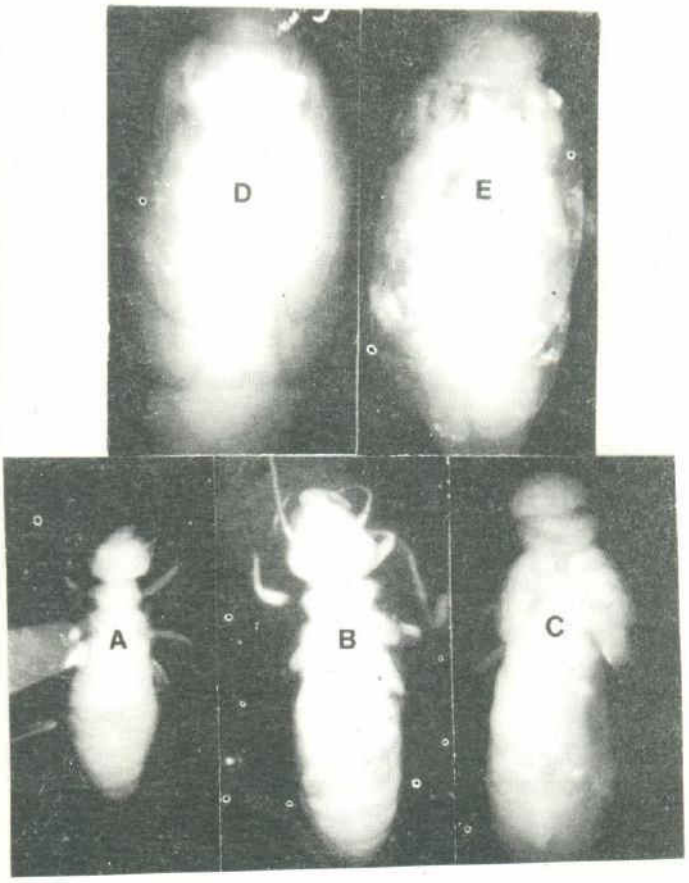


Plate III: Stages of development of wing pads during alate differentiation. A, first instar nymph; B, second instar nymph; C, third instar nymph; D, fourth instar nymph; E, fifth instar nymph.

completely pigmented. Antennae with 16 articles. Abdomen with a pair of styli. Tarsi 4-segmented (Table XVIII).

Table XVI. **Biometric analysis of different characters of second instar pre-soldier of *O. obesus* (measurements are in mm).**

Character	Range (n=10)	Mean±S.D.	C.V.
Total body length	3.48-3.74	3.63±0.077	2.13
Length of head to side base of mandibles	0.59-0.72	0.66±0.044	6.65
Maximum width of head	0.83-0.90	0.88±0.027	3.10
Length of left mandible	0.44-0.52	0.48±0.022	4.59
Length of hind tibia	0.72-0.77	0.75±0.015	1.99
Length of pronotum	0.23-0.31	0.28±0.028	9.75
Width of pronotum	0.46-0.59	0.52±0.050	9.60
Length of brain	0.28-0.34	0.31±0.091	6.16
Width of brain	0.52-0.59	0.56±0.025	4.48

Table XVII: **Biometric analysis of different characters of third instar pre-soldier of *O. obesus* (measurements are in mm).**

Character	Range (n=25)	Mean±S.D.	C.V.
Total body length	3.74-4.52	4.15±0.218	5.25
Length of head to side base of mandibles	0.88-1.01	0.95±0.030	3.16
Maximum width of head	0.98-1.08	1.04±0.033	3.14
Length of left mandible	0.88-0.93	0.91±0.014	1.51
Length of hind tibia	0.88-0.096	0.93±0.024	2.55
Length of pronotum	0.31-0.39	0.33±0.023	6.92
Width of pronotum	0.72-0.81	0.76±0.024	3.15
Length of brain (n=24)	0.31-0.41	0.34±0.028	8.27
Width of brain (n=24)	0.52-0.65	0.59±0.031	5.19

Fifth instar pre-soldier

Head rectangularly oval; head and abdomen much sclerotized than fourth instar pre-soldier. Mandibles darkly pigmented, more pointed (Plate 2E). Brain clearly visible, appearing smaller in comparison to the size of the head capsule. Antennae with 16 articles, dirty white throughout its length. Abdomen with a pair of styli. Tarsi 4-segmented (Table XIX).

Table XVIII: Biometric analysis of different characters of fourth instar pre-soldier of *O. obesus* (measurements are in mm).

Character	Range (n=10)	Mean±S.D.	C.V.
Total body length	4.52-4.90	4.69±0.121	2.57
Length of head to side base of mandibles	0.96-1.03	0.98±0.024	2.47
Maximum width of head	1.03-1.11	1.08±0.027	2.54
Length of left mandible	0.90-0.93	0.92±0.013	1.46
Length of hind tibia	0.93-0.98	0.96±0.017	1.78
Length of pronotum	0.34-0.41	0.38±0.021	5.65
Width of pronotum	0.75-0.88	0.79±0.047	5.98
Length of brain	0.31-0.41	0.35±0.040	11.41
Width of brain	0.54-0.62	0.60±0.027	4.53

Table XIX: Biometric analysis of different characters of fifth instar pre-soldier of *O. obesus* (measurements are in mm).

Character	Range (n=10)	Mean±S.D.	C.V.
Total body length	5.31-5.55	5.31±0.200	3.76
Length of head to side base of mandibles	1.34-1.50	1.42±0.053	3.77
Maximum width of head	1.29-1.37	1.31±0.024	1.87
Length of left mandible	0.96-1.06	1.01±0.028	2.82
Length of hind tibia	1.03-1.16	1.10±0.044	3.98
Length of pronotum	0.49-0.57	0.54±0.027	5.06
Width of pronotum	0.96-1.03	0.99±0.024	2.47
Length of brain	0.28-0.34	0.32±0.017	5.39
Width of brain	0.54-0.62	0.59±0.024	4.13

Mature soldier

Head rectangularly oval; head and abdomen fully sclerotized. Mandibles darkly pigmented, more pointed (Plate 2F). Brain visible in some specimens. Antennae with 16-17 articles, light brown throughout its length. Abdomen with a pair of styli. Tarsi 4-segmented (Table XX).

Comparison of different instars of soldiers of O. obesus

Total body length

Range, mean and standard deviation of different instars of soldiers for total body length are given in Table XXI. Frequency distribution of different instars of soldiers of *O. obesus* for total body length is illustrated in Fig.10.

Table XX: Biometric analysis of different characters of soldiers of *O. obesus* (measurements are in mm).

Character	Range (n=10)	Mean±S.D.	C.V.
Total body length	5.88-6.19	6.05±0.124	2.04
Length of head to side base of mandibles	1.42-1.50	1.45±0.034	2.33
Maximum width of head	1.32-1.39	1.35±0.025	1.84
Length of left mandible	1.01-1.06	1.04±0.018	1.69
Length of hind tibia	1.11-1.16	1.14±0.021	1.88
Length of pronotum	0.52-0.57	0.54±0.023	4.22
Width of pronotum	0.96-1.01	0.98±0.019	1.92
Length of brain	0.34-0.38(n=5)	0.36±0.022	6.04
Width of brain	0.57-0.62(n=5)	0.60±0.021	3.50

The co-efficient of variability was maximum (5.25) for third instar pre-soldier and was minimum for adult soldiers (Table XXI). Comparison of different instars of soldiers by student "t" test revealed significant differences ($P<0.05$).

Length of head to side base of mandibles

Range, mean and standard diviation of various instars of soldiers of *O. obesus* for length of head to side base of mandibles are given in Table XXI. Frequency distribution of different instars of soldiers is illustrated in Fig.11. The co-efficient of variability was maximum (6.65) for second instar pre-soldier, whereas it was minimum for adult soldiers. Comparison of different instars based on student "t" test revealed significant differences ($P<0.05$) between different instars. However, non-significant differences ($P>0.05$) were noted between fifth instar pre-soldier and adult soldier (Table XXI).

Maximum width of head

Range, mean and standard deviation of different instars of soldiers of *O. obesus* for maximum width of head are given in Table XXI. Frequency distribution of maximum width of head of different instars of soldiers of *O. obesus* is illustrated in Fig.12.

The co-efficient of variability is also indicated in Table XXI. As is indicated in Table maximum C.V. value was noted for third instar pre-soldiers, whereas, for adult soldier C.V. value was minimum.

Comparison of different instars of soldiers by student "t" test revealed significant differences ($P<0.05$) between all the instars (Table XXI).

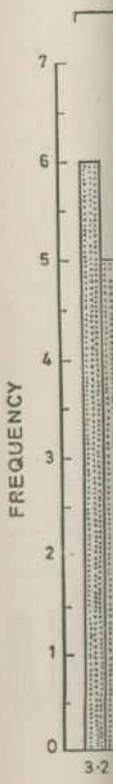


Fig. 10:

racters of soldiers of *O. obesus*

Mean±S.D.	C.V.
6.05±0.124	2.04
1.45±0.034	2.33
1.35±0.025	1.84
1.04±0.018	1.69
1.14±0.021	1.88
0.54±0.023	4.22
0.98±0.019	1.92
0.36±0.022	6.04
0.60±0.021	3.50

25) for third instar pre-soldier and ison of different instars of soldiers <0.05).

nstars of soldiers of *O. obesus* for Table XXI. Frequency distribution The co-efficient of variability was ereas it was minimum for adult udent "t" test revealed significant wever, non-significant differences nd adult soldier (Table XXI).

nstars of soldiers of *O. obesus* for equency distribution of maximum *us* is illustrated in Fig. 12.

n Table XXI. As is indicated in pre-soldiers, whereas, for adult

dent "t" test revealed significant I).

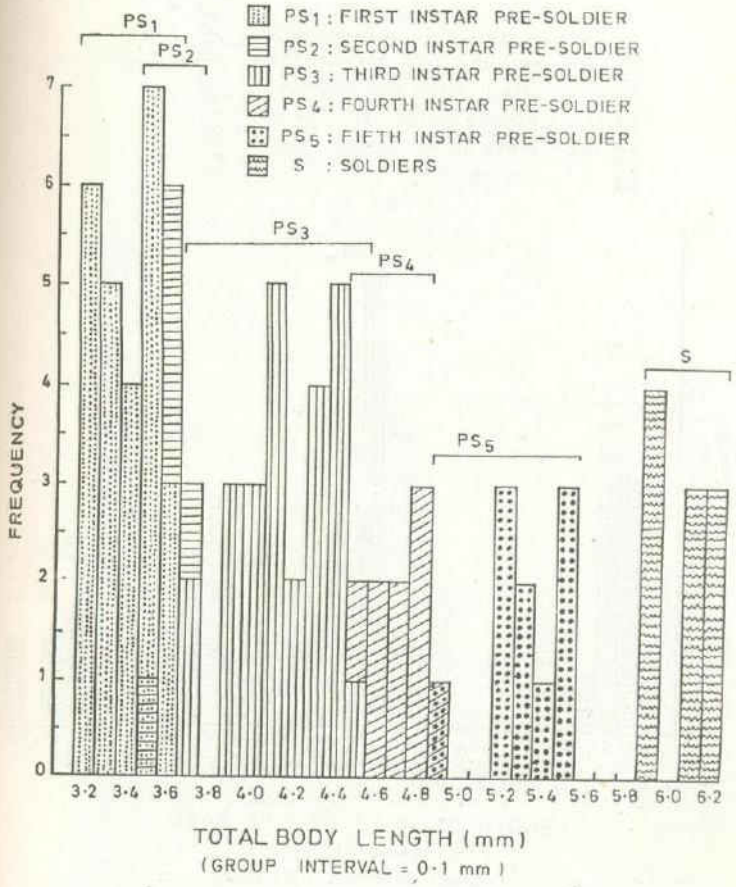


Fig. 10: **Frequency distribution of total body length in different instars of soldier line of *O. obesus*.**

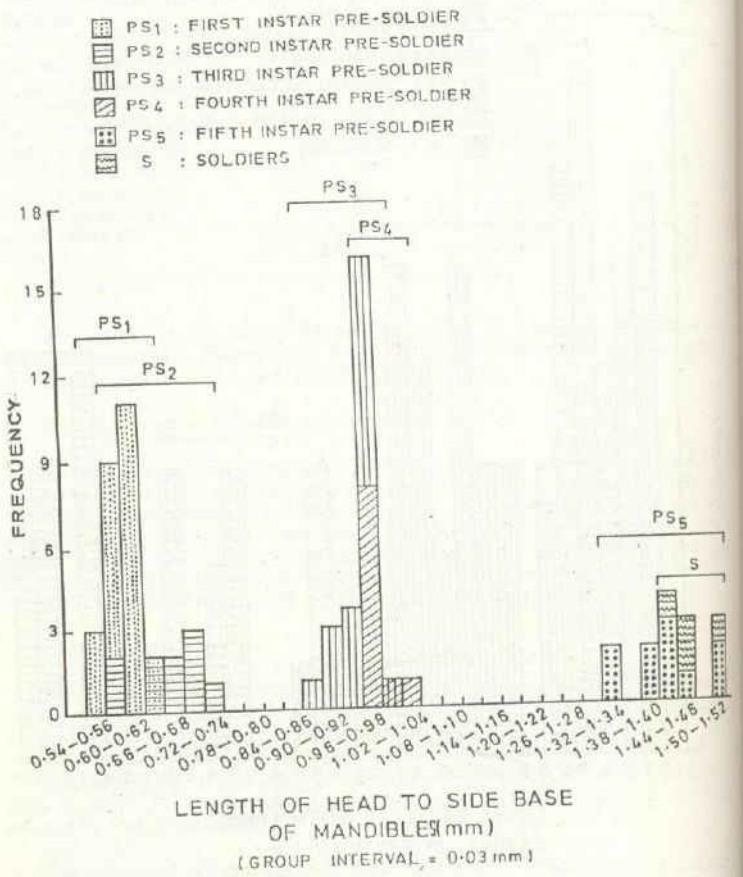
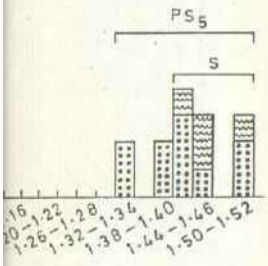


Fig. 11: Frequency distribution of length of head to side base of mandibles in differ instars of soldier line of *O. obesus*.



E BASE

(mm)

to side base of mandibles in different

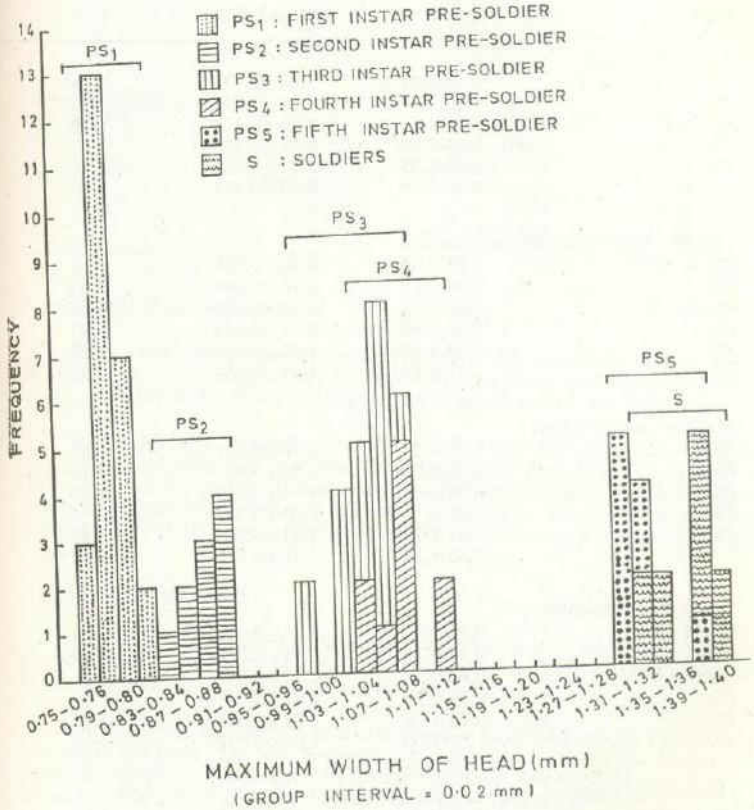


Fig. 12: **Frequency distribution of maximum width of head in different instars of soldier line of *O. obesus*.**

Table XXI: **Age variation in different parameters in measurement of different parameters of soldier instars of *O. obesus* (vertical lines alongside the instars indicate non-significant differences; P>0.05).**

Instar	Range (n=10)	Mean±S.D.	C.V.
Total body length			
PS_1 (n=25)	3.15-3.61	3.37±0.136	4.04
PS_2	3.48-3.74	3.63±0.077	2.13
PS_3 (n=25)	3.74-4.52	4.15±0.218	5.25
PS_4	4.52-4.90	4.69±0.121	2.57
PS_5	4.90-5.55	5.31±0.200	3.76
S	5.88-6.19	6.05±0.124	2.04
Length of head to side base of mandible			
PS_1 (n=25)	0.54-0.64	0.60±0.031	5.10
PS_2	0.59-0.72	0.66±0.044	6.65
PS_3 (n=25)	0.88-1.01	0.95±0.030	3.16
PS_4	0.96-1.03	0.98±0.024	2.47
PS_5	1.34-1.50	1.42±0.053	3.77
S	1.42-1.50	1.45±0.034	2.33
Maximum width of head			
PS_1 (n=25)	0.75-0.83	0.78±0.021	2.67
PS_2	0.83-0.90	0.88±0.027	3.10
PS_3 (n=25)	0.98-1.08	1.04±0.033	3.14
PS_4	1.03-1.11	1.08±0.027	2.54
PS_5	1.27-1.37	1.31±0.024	1.87
S	1.32-1.39	1.35±0.025	1.84
Length of left mandible			
PS_1 (n=25)	0.36-0.44	0.41±0.024	5.74
PS_2	0.44-0.52	0.48±0.022	4.59
PS_3 (n=25)	0.88-0.93	0.91±0.014	1.51
PS_4	0.90-0.93	0.92±0.013	1.46
PS_5	0.96-1.06	1.01±0.028	2.82
S	1.01-1.06	1.04±0.018	1.69
Length of hind tibia			
PS_1 (n=25)	0.67-0.72	0.70±0.018	2.56
PS_2	0.72-0.77	0.75±0.015	1.99
PS_3 (n=25)	0.88-0.96	0.93±0.024	2.55
PS_4	0.93-0.98	0.96±0.017	1.78
PS_5	1.03-1.16	1.10±0.044	3.98
S	1.11-1.16	1.14±0.021	1.88

Cont'd...

Length of pronotum			
PS_1 (n=25)	0.21-0.31	0.26±0.025	9.65
PS_2	0.23-0.31	0.28±0.028	9.75
PS_3 (n=25)	0.31-0.39	0.33±0.023	6.92
PS_4	0.34-0.41	0.38±0.021	5.65
PS_5	0.49-0.57	0.54±0.027	5.06
S	0.52-0.57	0.54±0.023	4.22
Width of pronotum			
PS_1 (n=25)	0.46-0.54	0.50±0.024	4.73
PS_2	0.46-0.59	0.52±0.050	9.60
PS_3 (n=25)	0.72-0.81	0.76±0.024	3.15
PS_4	0.75-0.88	0.79±0.047	5.98
PS_5	0.96-1.03	0.99±0.024	2.47
S	0.96-1.01	0.98±0.019	1.92

Length of left mandible

Range, mean and standard deviation of length of left mandible in different instars of soldiers of *O. obesus* are given in Table XXI. Frequency distribution of different instars of soldiers of *O. obesus* for length of left mandible is illustrated in Fig.13.

The co-efficient of variability is also indicated in Table XXI and was maximum for first instar pre-soldier and minimum for fourth instar pre-soldier. Comparison of different instars by student "t" test revealed significant differences between different instars of soldiers of *O. obesus* for length of left mandible. However, non-significant differences ($P>0.05$) were noticed between fifth instar pre-soldier and adult soldiers (Table XXI).

Length of hind tibia

Range, mean and standard deviation of different instars of soldiers of *O. obesus* for length of hind tibia are given in Table XXI. Frequency distribution of various instars of *O. obesus* for length of hind tibia is illustrated in Fig.14.

The co-efficient of variability is also indicated in Table XXI and was maximum for fifth instar pre-soldier and was minimum for fourth instar pre-soldiers. Comparison based on student "t" test revealed significant differences ($P<0.05$) between different instars of soldiers of *O. obesus* for length of hind tibia (Table XXI).

Length of pronotum

Range, mean and standard deviation of different instars of soldiers of *O. obesus* for length of pronotum are given in Table XXI. Frequency distribution of different instars of soldiers of *O. obesus* for length of pronotum is illustrated in Fig.15.

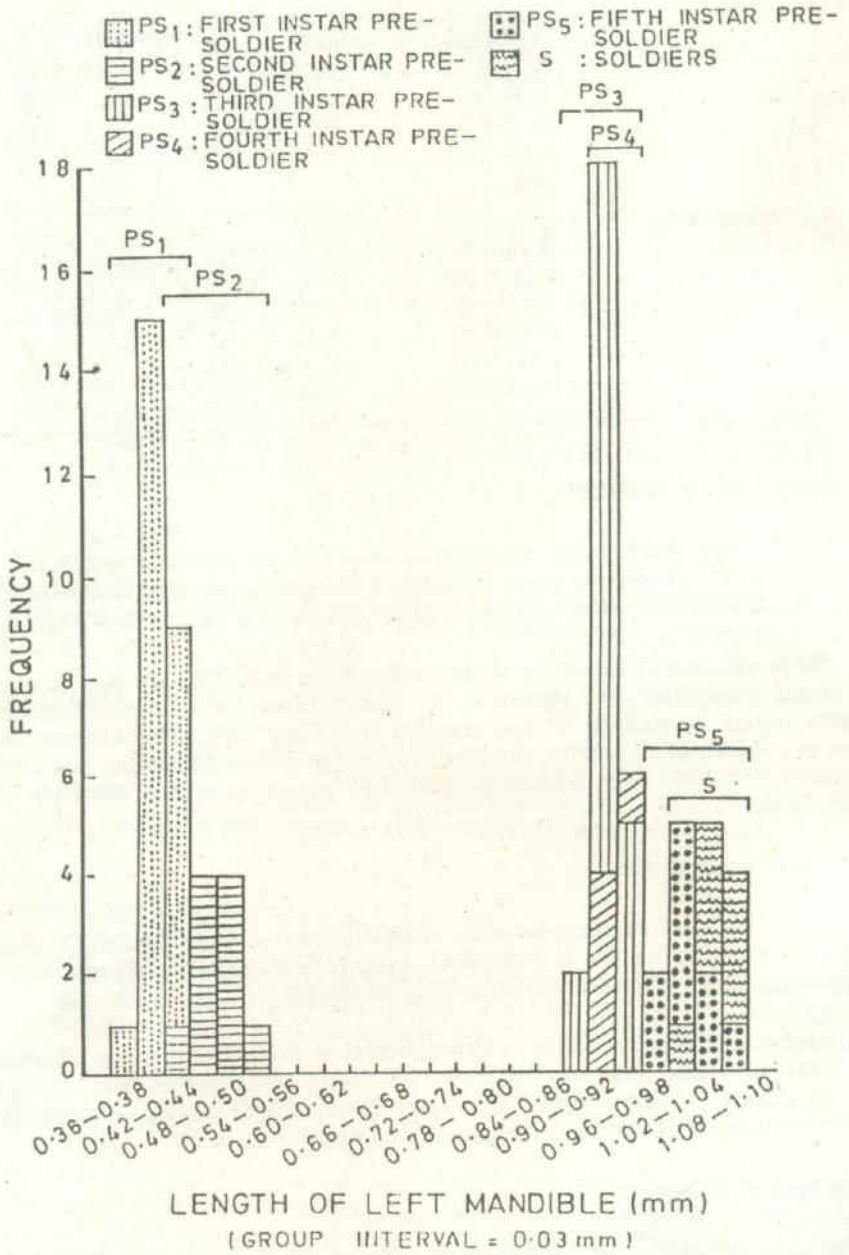


Fig. 13: **Frequency distribution of length of left mandible in different instars of soldier line of *O. obesus*.**

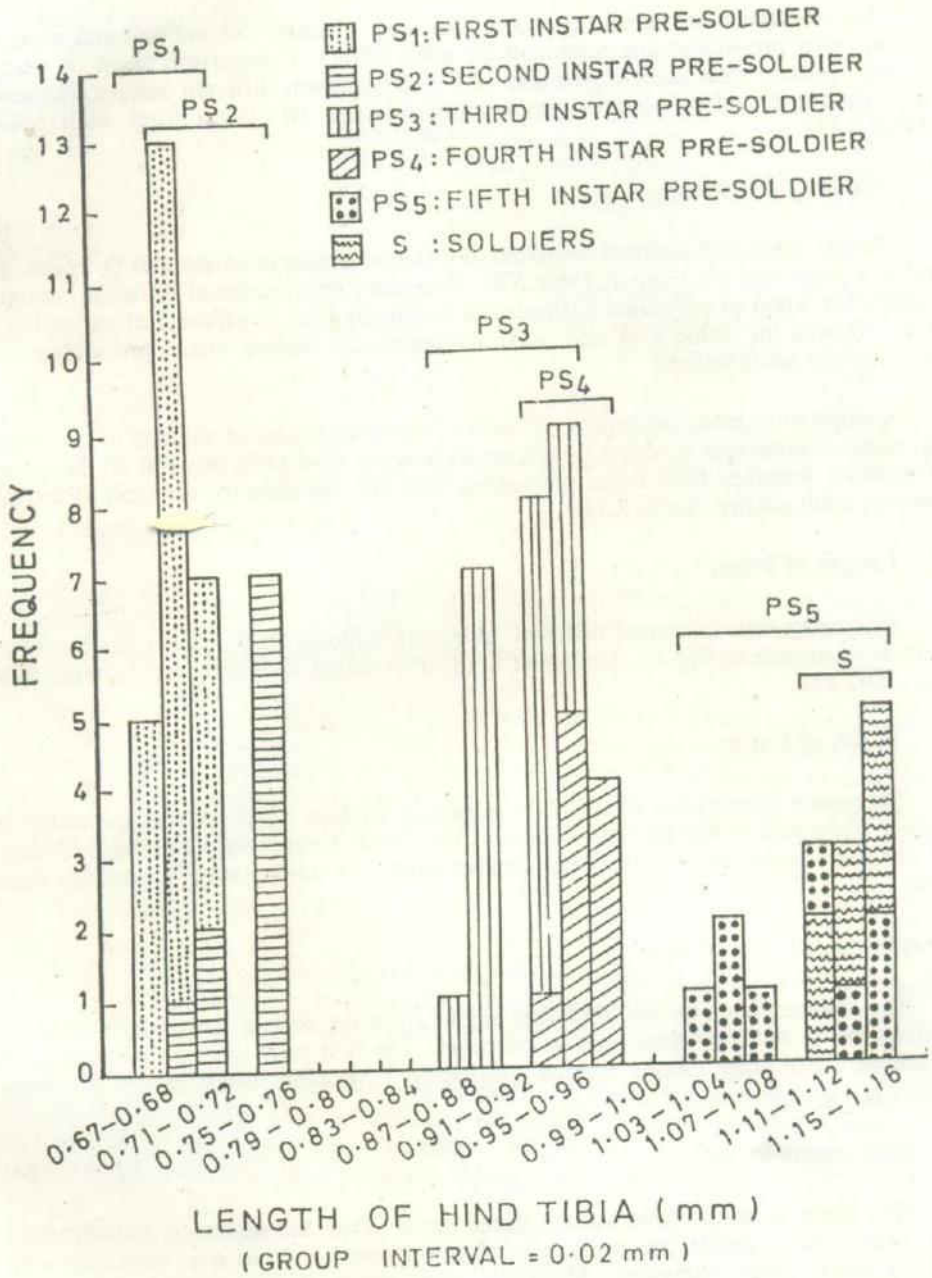


Fig. 14: **Frequency distribution of length of hind tibia in different instars of soldier line of *O. obesus*.**

The co-efficient of variability is also indicated in Table XXI and was maximum for second instar pre-soldier and minimum for adult soldier. Comparison based on student "t" test revealed significant differences ($P<0.05$) between different instars. However, fifth instar pre-soldier was not significantly different ($P>0.05$) from adult soldier (Table XXI).

Width of pronotum

Range, mean and standard deviation of different instars of soldiers of *O. obesus* for width of pronotum are given in Table XXI. Frequency distribution of different instars of soldiers for width of pronotum is illustrated in Fig.16. The co-efficient of variability is also indicated in Table XXI and was maximum for second instar pre-soldier and minimum for adult soldier.

Comparison (based on student "t" test) of different instars of soldiers of *O. obesus* for width of pronotum revealed significant differences ($P<0.05$) between all the instars of soldiers, however fifth instar pre-soldier was not significantly different ($P>0.05$) from the adult soldier (Table XXI).

Length of brain

Frequency distribution of different instars of soldiers of *O. obesus* for length of brain is illustrated in Fig.17. Length of brain in different instars ranged between 0.26 mm - 0.42 mm.

Width of brain

Frequency distribution of different instars of soldiers of *O. obesus* for width of brain is illustrated in Fig.18. Brain width of first instar ranged between 0.49-0.65 mm. All the other instars have brain width smaller than first instar except pre-soldier third instar.

Developmental line of alate

The differentiation of the alate line begins from the second larval stage which is common to the developmental lines of all castes. The first stage nymph emerging from the second larval stage moults 5 times, producing 5 nymphal instars before becoming adult (Fig.1).

First instar nymph

This instar develops from second instar larva. Head and abdomen whitish, head oval; brain clearly visible but much reduced as compared to head size. Antennae with 16-17 articles, much elongated. Mandibles with apical, first marginal and second marginal teeth slightly indicated. Thorax broader than second larval instar, mesothorax and metathorax with slight indication of wing pads (Plate 3A), abdomen with a pair of cerci and a pair of styli, Tarsi 4-segmented (Table XXII).

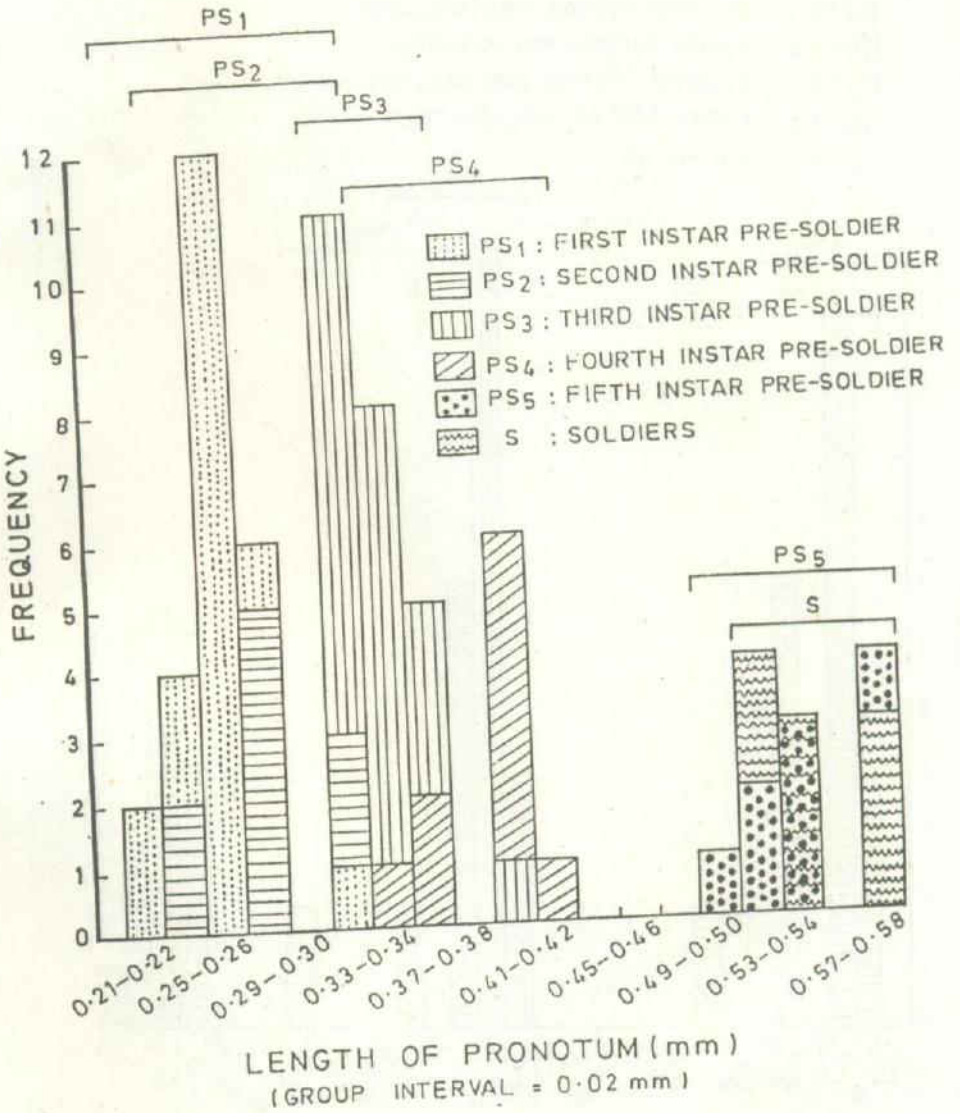


Fig. 15: **Frequency distribution of length of pronotum in different instars of soldier line of *O. obesus*.**

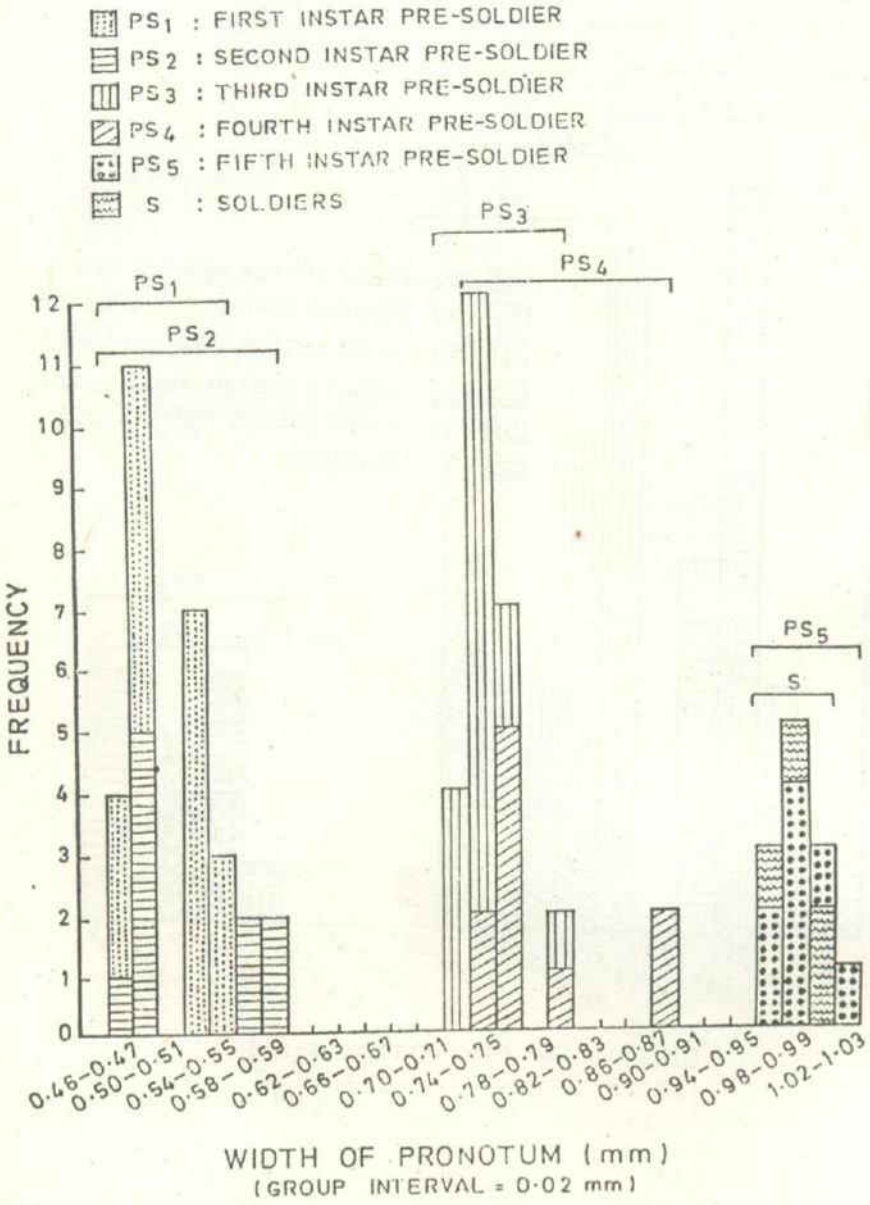


Fig. 16: **Frequency distribution of width of pronotum in different instars of soldier line of *O. obesus*.**

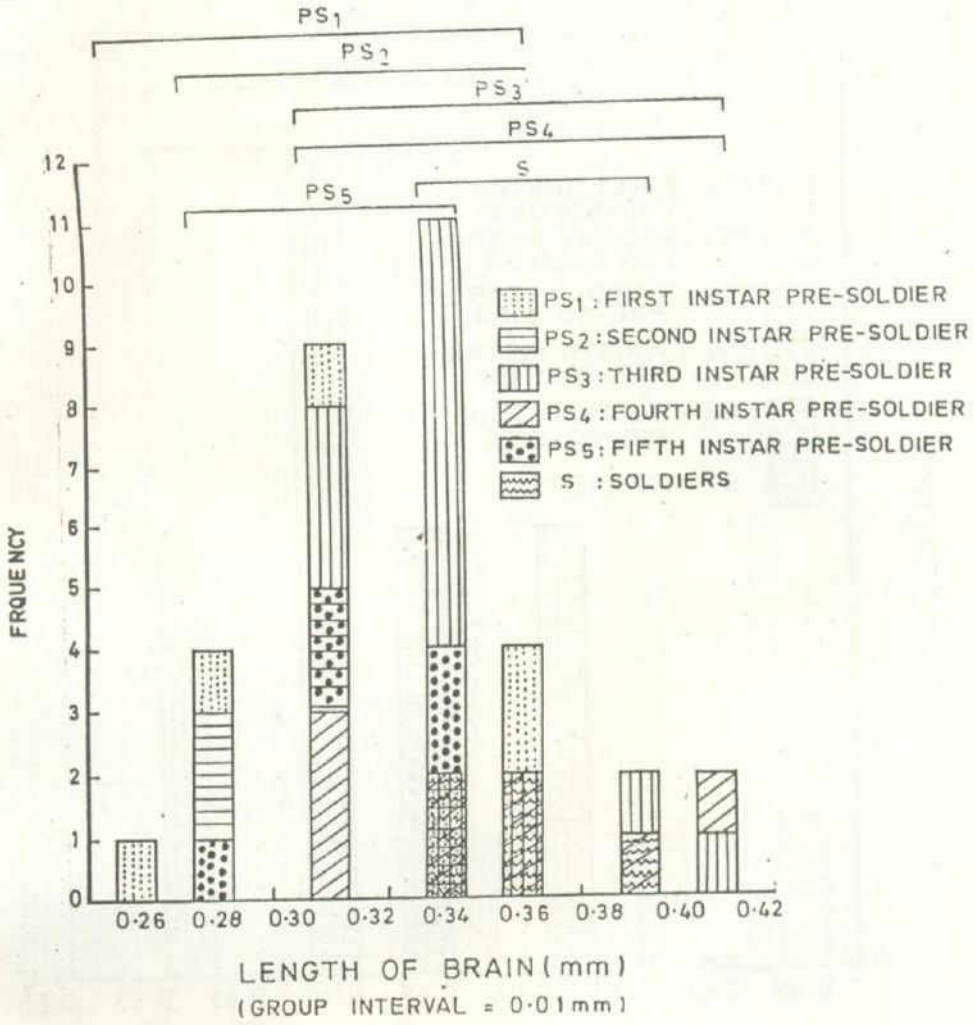


Fig. 17: **Frequency distribution of length of brain in different instars of soldier line of *O. obesus*.**

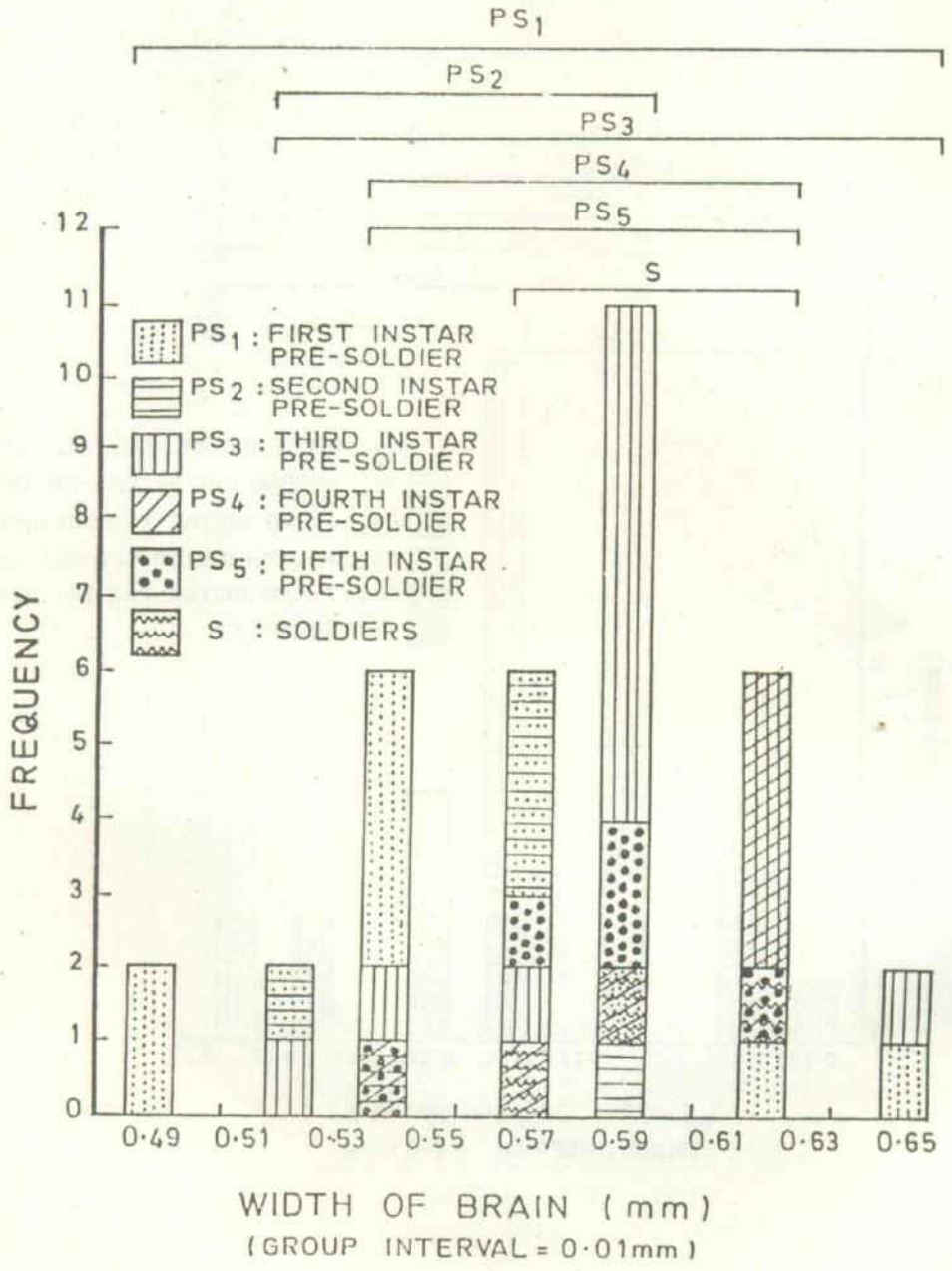


Fig. 18: Frequency distribution of width of brain in different instars of soldier line of *O. obesus*.

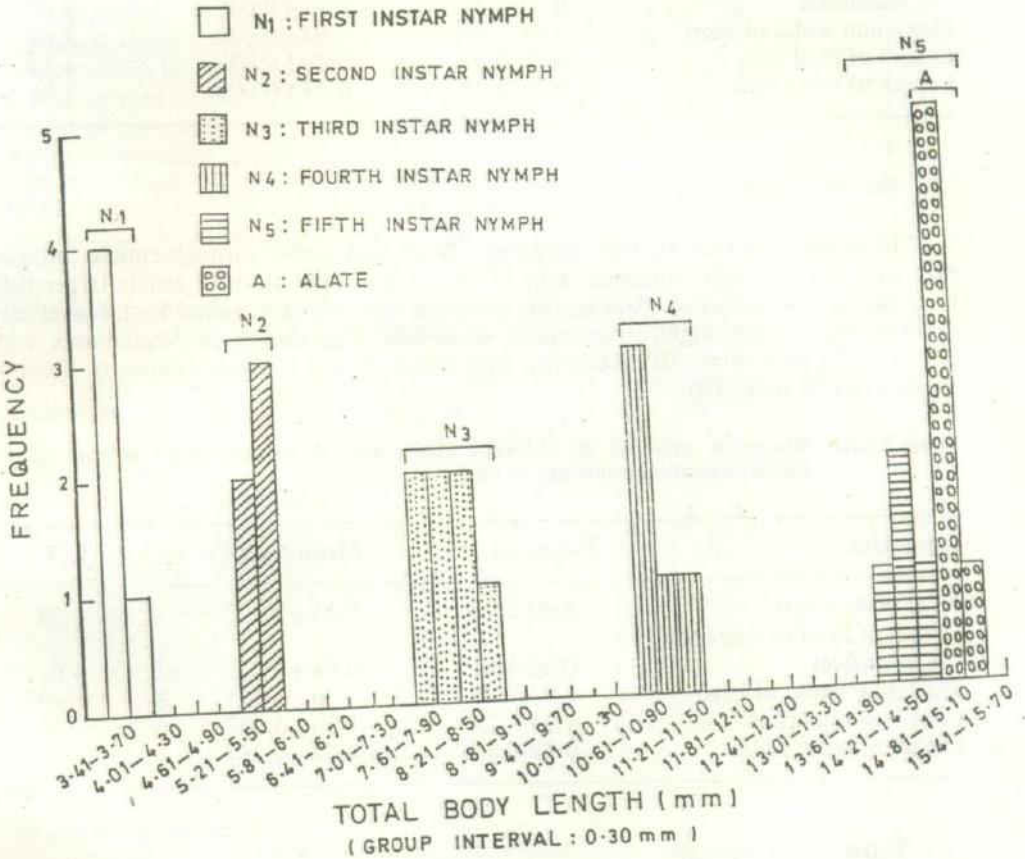


Fig. 19: **Frequency distribution of total body length in different instars of alate of *O. obesus*.**

Table XXII: Biometric analysis of different characters of first instar nymph of *O. obesus* (measurements are in mm).

Character	Range (n=5)	Mean±S.D.	C.V.
Total body length	3.48-3.77	3.63±0.112	3.10
Length of head to side base of mandibles	0.77-0.85	0.81±0.041	5.03
Maximum width of head	0.98-1.08	1.04±0.038	3.65
Length of hind tibia	0.77-0.83	0.79±0.033	4.14
Length of wing pads	0.21-0.23	0.23±0.009	3.96

Second instar nymph

Head and abdomen whitish, head oval. Brain area visible through cuticle, broader than first instar nymph. Antennae with 17-18 articles. First antennal article larger than third and fourth combined. Apical, first marginal and second marginal teeth completely differentiated. Teeth slightly pigmented, brownish. Mesothorax and metathorax with distinct wing pads (Plate 3B). Abdomen with a pair of cerci in some specimens. Tarsi 4-segmented (Table XXIII).

Table XXIII: Biometric analysis of different characters of second instar nymph of *O. obesus* (measurements are in mm).

Character	Range (n=5)	Mean±S.D.	C.V.
Total body length	5.42-5.68	5.55±0.107	1.92
Length of head to side base of mandibles	0.90-1.01	0.98±0.045	4.62
Maximum width of head	1.24-1.29	1.26±0.025	1.99
Length of hind tibia	1.24-1.34	1.30±0.037	2.85
Length of wing pads	0.59-0.72	0.67±0.057	8.60

Third instar nymph

Head and abdomen whitish. Head nearly round. Brain larger than second instar nymph. Antennae with 19 antennal articles. Differentiation of teeth more pronounced, slightly more pigmented than second instar nymph. Eyes slightly indicated. Thorax with wing pads longer than second instar nymph, extending up to 1/4 of abdomen (Plate 3C). Styli present in some specimens. Tarsi 4-segmented (Table XXIV).

Table XXIV: Biometric analysis of different characters of third instar nymph of *O. obesus* (measurements are in mm).

Character	Range (n=7)	Mean±S.D.	C.V.
Total body length	7.74-8.51	8.11±0.267	3.29
Length of head to side base of mandibles	1.08-1.24	1.15±0.067	5.81
Maximum width of head	1.60-1.75	1.68±0.059	3.53
Length of hind tibia	1.70-1.81	1.74±0.038	2.16
Length of wing pads	1.68-1.86	1.77±0.060	3.40

Fourth instar nymph

Head and abdomen dirty white, head nearly round with minute bristles and hairs. Labrum whitish. Mandibles more pigmented than third instar nymph. Eyes clearly indicated, much darker. Antennae with 19 articles. Thorax with wing pads larger than third instar nymph covering nearly 7/8 part of abdomen (Plate 3D). Styli present in some specimens. Tarsi 4-segmented (Table XXV).

Table XXV: Biometric analysis of different characters of fourth instar nymph of *O. obesus* (measurements are in mm).

Character	Range (n=5)	Mean±S.D.	C.V.
Total body length	10.53-10.96	10.67±0.174	1.63
Length of head to side base of mandibles	1.50-1.57	1.54±0.028	1.80
Maximum width of head	2.09-2.27	2.16±0.067	3.09
Length of hind tibia	2.06-2.32	2.20±0.096	4.36
Length of wing pads	4.95-5.21	5.09±0.103	2.03

Fifth instar nymph

Head light brown, brain not visible through cuticle of head. Eyes large, well developed, separated from the lower margin of head by nearly one fifth of its long diameter. Ocellus slightly indicated. Mandibles more pigmented than fourth instar nymph. Teeth of mandibles dark brown with blackish tinge. Antennae with 19 articles, slightly brownish. Wing pads light brown (Plate 3E). Abdomen slightly pigmented, clear indication of abdominal segments. Tarsi 4-segmented (Table XXVI).

Table XXVI: Biometric analysis of different characters of fifth instar nymph of *O. obesus* (measurements are in mm).

Character	Range (n=10)	Mean±S.D.	C.V.
Total body length	14.19-15.22	14.77±0.332	2.25
Length of head to side base of mandibles	1.81-1.93	1.86±0.036	1.93
Maximum width of head	2.27-2.40	2.32±0.043	1.86
Length of hind tibia	2.42-2.58	2.49±0.043	1.73
Length of wing pads	5.42-5.78	5.61±0.121	2.15

Alate

Head slightly reddish brown, brain not visible through cuticle. Eyes fully developed. Ocellus large, oval, clearly indicated. Antennae with 19 antennal articles, reddish brown. Postclypeus strongly arched. Wings fully developed, reddish brown. Labrum larger than wide. Tarsi 4-segmented (Table XXVII).

Table XXVII: Biometric analysis of different characters of alates of *O. obesus* (measurements are in mm).

Character	Range (n=5)	Mean±S.D.	C.V.
Total body length	14.83-15.22	15.04±0.148	0.99
Length of head to side base of mandibles	1.86-1.93	1.88±0.029	1.52
Maximum width of head	2.58-2.68	2.61±0.042	1.61
Length of hind tibia	2.68-2.83	2.75±0.121	2.12

Comparison of different instars of alate line of O. obesus

Total body length

The range, mean and standard deviation of total body length of different instars of alate line of *O. obesus* are given in Table XXVIII. Frequency distribution of total body length of different instars is illustrated in Fig.19.

The co-efficient of variability (Table XXVIII) was maximum for third instar nymph, whereas, it was minimum for alates, indicating that the growth has completed and the specimens are therefore relatively less variable. Comparison of different instars of alate line of *O. obesus* for total body length was carried out by student "t" test, which revealed significant differences between all the instars except in the case of fifth instar nymph which was not significantly different ($P>0.05$) from alates.

Table XXVIII: Age variation in different instars of alate line of *O. obesus* (vertical lines alongside the instars indicate non-significant differences; P > 0.05).

Instar	Range (n=5)	Mean±S.D.	C.V.
Total body length			
N_1	3.48-3.77	3.63±0.112	3.10
N_2	5.42-5.68	5.55±0.107	1.92
N_3 (n=7)	7.74-8.51	8.11±0.267	3.29
N_4	10.53-10.96	10.67±0.174	1.63
N_5 (n=10)	14.19-15.22	14.77±0.332	2.25
A	14.83-15.22	15.04±0.148	0.99
Length of head to side base of mandibles			
N_1	0.77-0.85	0.81±0.041	5.03
N_2	0.90-1.01	0.98±0.045	4.62
N_3 (n=7)	1.08-1.24	1.15±0.067	5.81
N_4	1.50-1.57	1.54±0.028	1.80
N_5 (n=10)	1.81-1.93	1.86±0.036	1.93
A	1.86-1.93	1.88±0.029	1.52
Maximum width of head			
N_1	0.98-1.08	1.04±0.038	3.65
N_2	1.24-1.29	1.26±0.025	1.99
N_3 (n=7)	1.60-1.75	1.68±0.059	3.53
N_4	2.09-2.27	2.16±0.067	3.09
N_5 (n=10)	2.27-2.40	2.32±0.043	1.86
A	2.58-2.68	2.61±0.042	1.61
Length of hind tibia			
N_1	0.77-0.83	0.79±0.033	4.14
N_2	1.24-1.34	1.30±0.037	2.85
N_3 (n=7)	1.70-1.81	1.74±0.038	2.16
N_4	2.05-2.32	2.20±0.096	4.36
N_5 (n=10)	2.42-2.58	2.49±0.043	1.73
A	2.68-2.83	2.75±0.121	2.12
Length of wing pads			
N_1	0.21-0.23	0.23±0.009	3.96
N_2	0.59-0.72	0.67±0.057	8.60
N_3 (n=7)	1.68-1.86	1.77±0.060	3.40
N_4	4.95-5.21	5.09±0.103	2.03
N_5 (n=10)	5.42-5.78	5.61±0.121	2.15

Length of head to side base of mandibles

The range, mean and standard deviation of length of head to side base of mandibles for different instars of alate line of *O. obesus* are given in Table XXVIII. Frequency distribution of length of head to side base of mandibles of different instars is illustrated in Fig.20.

The co-efficient of variability was maximum for third instar nymph and was minimum for alates of *O. obesus* (Table XXVIII). Comparison of different instars of alate line of *O. obesus* was carried out by student "t" test. There were significant differences ($P<0.05$) between different instars of alate of *O. obesus*. However, fifth instar nymph was not significantly different from alates.

Maximum width of head

The range, mean and standard deviation of different instars of alate line of *O. obesus* for maximum width of head are given in Table XXVIII. Frequency distribution of maximum width of head of alate of *O. obesus* is illustrated in Fig.21.

The co-efficient of variability was maximum (3.65) for first instar nymph, whereas it was minimum (1.61) for alates. Comparison of different instars of alate line of *O. obesus* for maximum width of head was carried out by student "t" test, which revealed significant differences ($P<0.05$) between all the instars.

Length of hind tibia

The range, mean and standard deviation of different instars of alate line of *O. obesus* for length of hind tibia are given in Table XXVIII. Frequency distribution of different instars is illustrated in Fig.22.

The co-efficient of variability was maximum for fourth instar nymph, whereas it was minimum for fifth instar nymph (Table XXVIII). Comparison of different instars of alate line for length of hind tibia of *O. obesus* revealed singificant differences ($P<0.05$).

Length of wing pads

The range, mean and standard deviation of length of wing pads for different instars of alate line of *O. obesus* are given in Table XXVIII. Frequency distribution of different instars for length of wing pags is illustrated in Fig.23.

The co-efficient of variability was maximum for second instar nymph and was minimum for fourth instar nymph (Table XXVIII).

Comparison of different instars of alate line of *O. obesus* for length of wing pads was carried out by student "t" test, which revealed singificant differences ($P<0.05$) between all the instars.

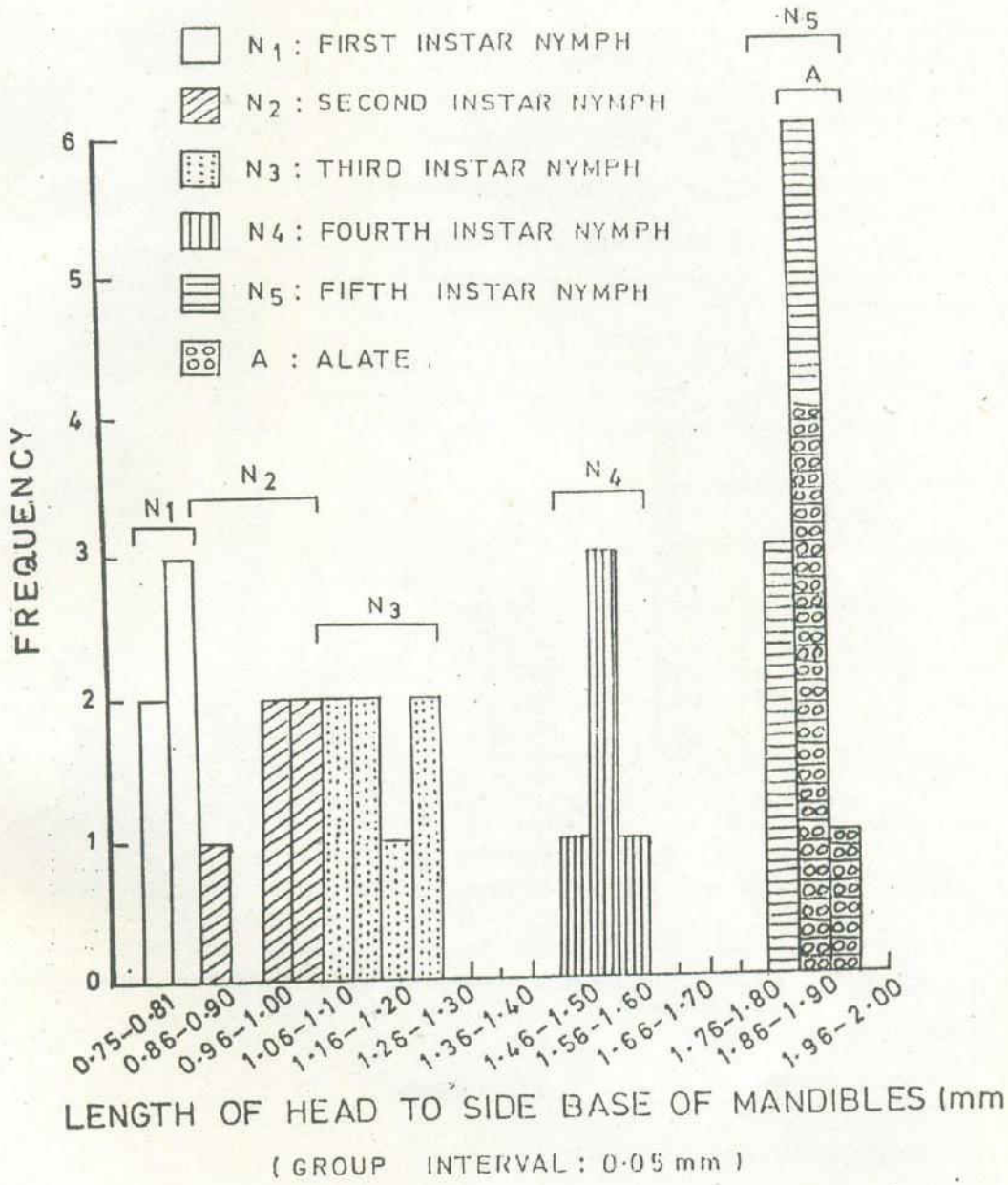


Fig. 20: **Frequency distribution of length of head to side base of mandibles in different instars of alate of *O. obesus*.**

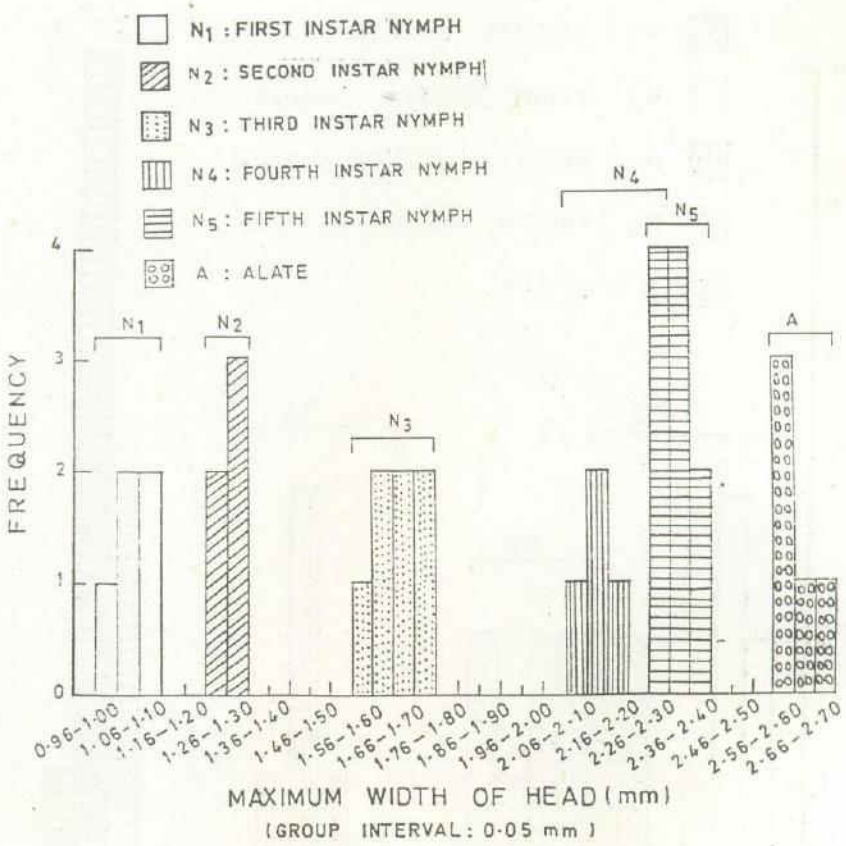


Fig. 21: **Frequency distribution of maximum width of head of different instars of alate line of *O. obesus*.**

DISCUSSION

Developmental lines of workers

In the field collections of *O. obesus*, two types of workers, major and minor, were detected. The major and minor workers are as distinct as in the fungus growing termites belonging to the genus *Macrotermes*. Nevertheless, they can be distinguished by

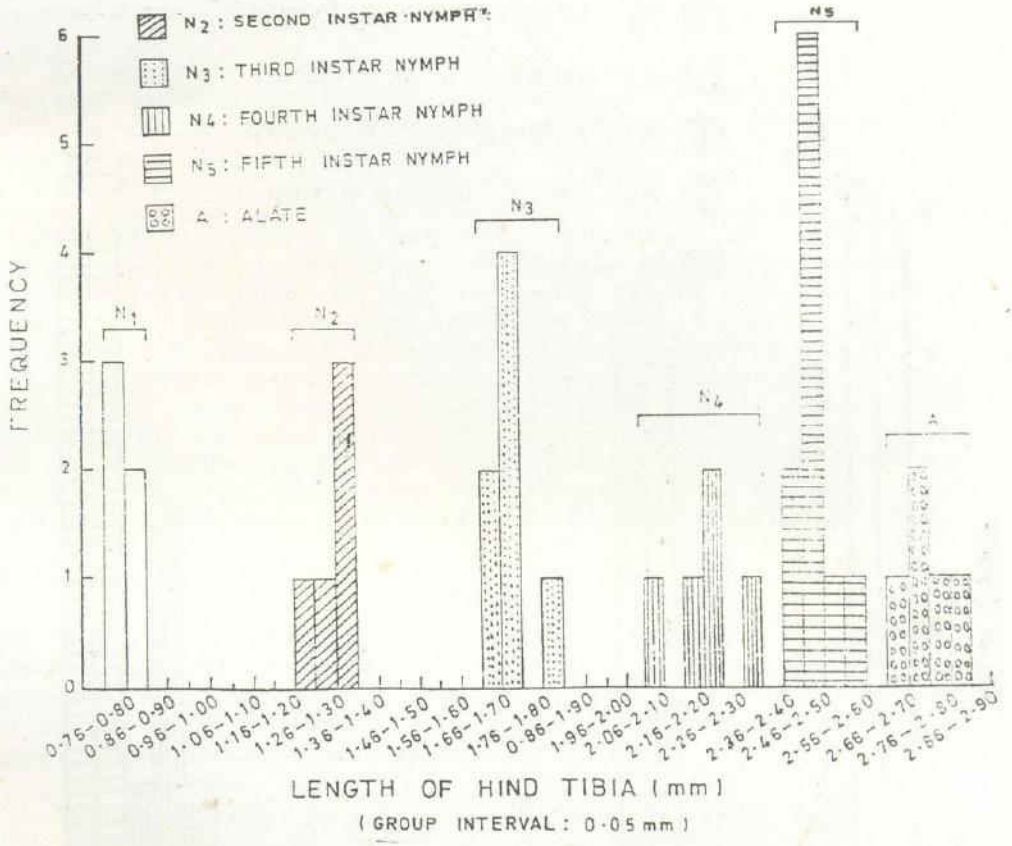


Fig. 22: **Frequency distribution of length of hind tibia in different instars of alate line of *O. obesus*.**

differences in their mandibular shape (not pattern) and also by the differences in the measurements (Table VIII and XIV). Okot-Kotber (1985) has reported that besides other morphological differences, sex differences also exist in the major and minor workers of *M. michaelseni*. Major workers develop from third instar male larvae, whereas the minor workers develop from female third instar larvae.

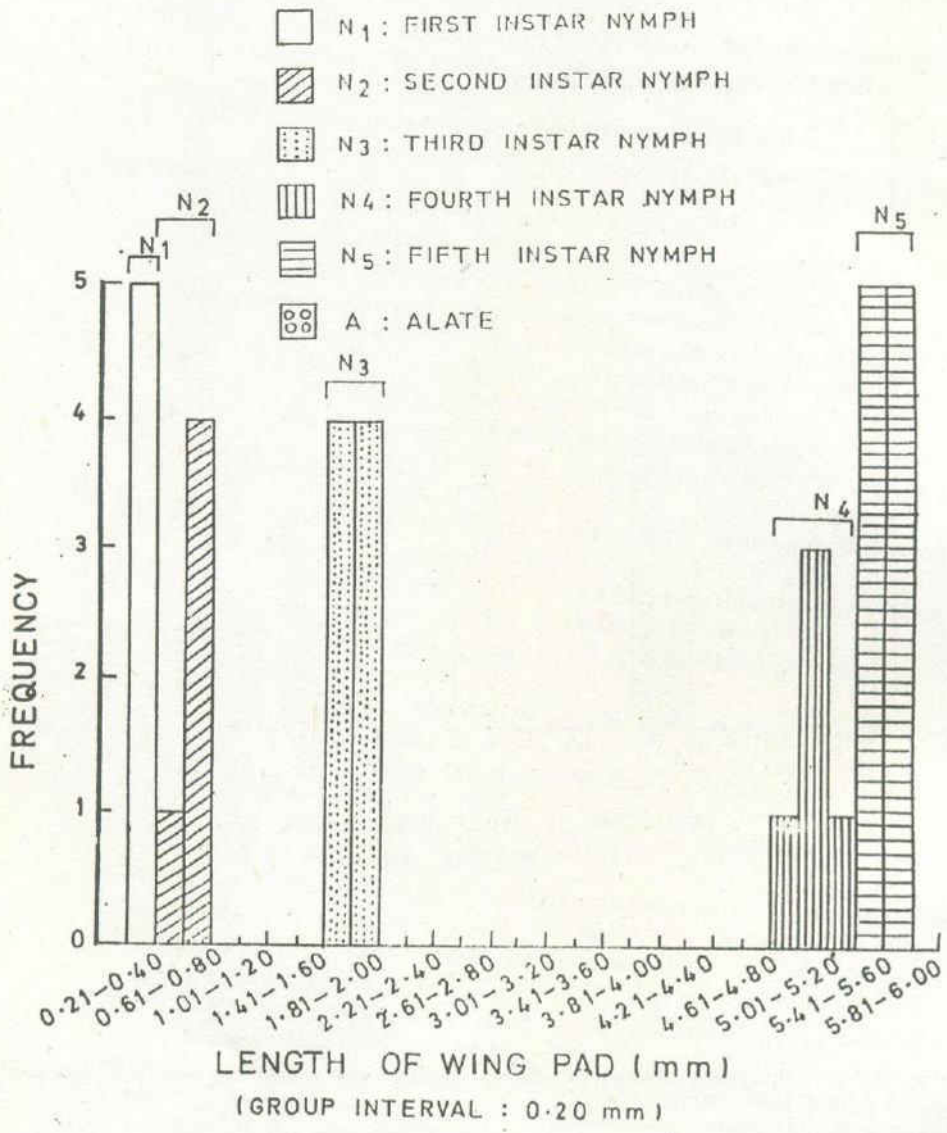


Fig. 23: **Frequency distribution of length of wind pads of different instars of alate line of *O. obesus*.**

Noirot (1985b) has reported that the workers are preceded by two larval stages in all the Termitidae except the fungus growing Macrotermitinae in which the workers are preceded by three larval instars. The present study supports Noirot in that the workers of *O. obesus* also develops from third instar larva.

The developmental stages through which the worker passes after differentiation from third instar larva may vary in the Macrotermitinae (Noirot, 1985b). The workers after emergence from the third larval instar may pass through one stage before becoming adult. The intermediate stage between the last larval and the adult stage has been referred to as "unpigmented stage" (Luscher, 1976). However, Okot-Kotber (1985) report that in case of *Macrotermes michaelseni*, the third stage larva moults into adult workers, both major and minor. There is no unpigmented stage in between. The result of the present biometrical study of the immature stages of *O. obesus*, however, differ significantly from those reported in the case of *M. michaelseni*, the only other fungus growing termite whose caste differentiation has been studied in detail. The workers (both major and minor) of *O. obesus* undergo three moults after coming out from the third instar larva; adult workers represent the fourth and final stage. Biometrically all the three instars of the workers (both major and minor) of *O. obesus* were found to be significantly different (Tables VIII and XIV) except for the total body length, which in the case of third instar major worker and adult major workers vary little. Biometric studies by Akhtar and Rana (1988)on caste polymorphism in a field colony of *O. gurdaspurensis* revealed that worker passes through five instars before becoming adult.

Developmental line of soldier

The soldier developmental line is an off-shoot from the third larval instar from which also arises the developmental line of minor worker. The pre-soldiers in *O. obesus* undergoes 5 moults before becoming adult. The rectangularly oval head characteristics of the species is visible in the last (5th) stage leading to the adults. In the preceding instars the head capsule remained nearly round.

Okot-Kotber (1985) reports that in *M. michaelseni* soldiers develop from the third instar larva. In *M. bellicosus* minor soldier originate from third instar larva, whereas origin of major soldier takes place from first instar minor worker (Luscher, 1976). Akhtar and Rana (1988) stated that soldiers in *O. gurdaspurensis* develop from third instar major worker larva and after seven moults develops into adult soldiers.

Developmental line of alates

The present studies on developmental lines of *O. obesus* revealed that the origin of alate line takes place from the second instar larva and nymph after 5 significantly different instars develops into alate. In *M. bellicosus* five nymphal instars have been recorded by Luscher (1976). Okot-Kother (1985) has also reported five nymphal stages upto alate after first instar larva in *M. michaelseni*.

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