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Chromo-Ecological studies of two short horn Grasshoppers, *Phlaeoba infumata* Brunner and *Oedaleus abruptus* Thunberg (Orthoptera: Acrididae)

M. E. Hassan

Abstract
Two very common short horn grasshoppers, *Phlaeoba infumata* and *Oedaleus abruptus* in Aligarh district were studied under different ecological conditions (27±1 °C and 37±1 °C and isolated & crowded) in order to estimate magnitude of swarming behaviour on the basis of colour changes. The colour changes of head and prothorax of these grasshoppers in all hopper instars and adult stages, both in male and female were critically observed and drawn as colour plates.

Keywords: Acrididae, *Phlaeoba infumata*, *Oedaleus abruptus*, Chromo-ecology, swarming behaviour

1. Introduction
For thousands of years, grasshoppers and locusts have been among the most destructive pests of agricultural crops and there is no stretch of land free from them. Grasshopper species compete with the human for plant resources all over the world and hence threatens human prosperity and survival [3].
Okay [10], [11] made useful investigations of the changes in colour patterns among the Orthopterans. Some sporadic reports have been published on colouration associated with microhabitat or as behavioural pigmentation depiction or as a cryptic behaviour presentation by Colvin and Cooter [2], Eterovick *et al*. [3], Islam [5], Konno [8], and Sword and Simpson [12]. But recently Badruddin *et al* [1]. And Khan *et al*. [6] have experimentally proved that the acridid colouration under abiotic and biotic factors can be used as bioindicators for the environmental changes.
Uvarov [13] has proposed a theory that each species of locust can exist in two main forms ('Phases'), which differ structurally and biologically. These are the gregarious phase (*Phasis gregaria*) and the Solitary phase (*Phasis solitaria*) and the two are often so distinct as to have been regarded by earlier taxonomists as separate species. Intermediates (*Phasis transiens*) also occur during the transition of population from one extreme to another.
Adults of *Phlaeoba infumata* are medium sized and distributed in India (Bihar, Orissa and Uttar Pradesh), East Nepal, Myanmar, Thailand, Malaysia and China. Both adult and their hoppers are a serious pest of economically important grasses and a number of agricultural crops like wheat, sugarcane, millet, maize, and rice, which make them as polyphagous in nature. Apart from these it was found to be a serious pest of bamboo in China and recently assumed to be a pest of a number of medicinal plants. *Oedaleus abruptus* inhibit short and dry grasses, and it was found to be a periodically major pest of millet with 3-4 overlapped generations a year and cause damage to a number of cultivated crops in North India and also reported from different geographical areas throughout the globe especially from African countries. Khan and Aziz [7] observed *Oedaleus abruptus* as an important polyphagous pest with two generations a year, and being found throughout the year except during very hot and cold periods.
The present work is a preliminary attempt to correlation swarming behaviour and phase transformation with the chromo-ecology characteristics in these two short horn grasshoppers on the basis of colour changes in deferent ecological conditions.

2. Materials and Methods
In order to maintain stock in the laboratory large number of mature adults and immature stages of *Phlaeoba infumata* and *Oedaleus abruptus* were collected from different localities in

Aligarh (Lat. 27 º 34' 30" N and Long. 78º 4' 26" E). They were reared in wooden insect breeding cages. Chromo-ecology of these grasshoppers was studied under different ecological conditions to evaluate magnitude of swarming behaviour. To study the colour patterns, only head and pronotum was taken into account as they exhibit prominent colour components. Colour changes were observed visually, using hand lens and under light microscope. Colour variations were recorded in the form of colour plates under above said ecological conditions and deciphered using colour dictionary by Maerz and Paul [9].

3. Observations

The colour changes of head and prothorax (pronotum) of these grasshoppers were critically observed and drawn colour diagrams with all possible care. Female hopper individuals were chosen as model for colour depiction. In case of adult both sexes were considered due to appreciable colour changes under different ecological conditions. The colour patterns observed in these two grasshoppers are not based on individual but a model colour pattern was recorded based on exhibited by the majority under given ecological conditions. (Plates 01-14).

I. Description of colour patterns in *Phlaeoba infumata*

(i) Ist Instar Hoppers

Dorsal view

(a) Head

No marked differences were observed in the ground colour under all ecological conditions. A slightly different colour, Italian straw (11D2) and Cockatoo (10H2) were observed at 27±1 °C and 37±1°C respectively. Similarly, colour of streaks observed as Bonito Fuscous+ (7C7) at 27±1 °C, while Natal Brown (7A10) at 37±1 °C. Colours of dots were similar for both high temperatures and low temperatures. Influence of crowded condition was not noticed.

(b) Pronotum

Only Italian Straw (11D2) as ground colour was observed under all ecological conditions. Similarly, sunstone (12F12) was observed for dots.

Lateral view

(a) Head

Pineapple+ (12J2) was most prominent ground colour with a slight change at 27±1 °C under isolated condition.

(b) Pronotum

Again Pineapple + was most prominent ground colour in all ecological conditions provided. Colours of dots were same through- out the instars under all ecological conditions.

(ii) II nd Instar Hoppers

Dorsal View

(a) Head

Slight change in ground colour was observed at two different temperatures. Colour was more prominent at 37±1 °C (Seminole– 14E10), while less intensified at 27±1 °C (Airedale–14F6). Colour of streaks were found to be Cub–15C1 for each experimental conditions except at high temperature and crowded condition, where colour was more intense (English Grey–15C2). In case of dots two slightly different colours were observed in low temperature, while influence of crowded condition was not prominent.

(b) Pronotum

Background colour observed was ACORN–15E7 at high temperature. Colour of streaks were almost similar except at 37±1 °C under crowded condition which was observed as brown sugar–15H11. Colour of the dots was Sooty Black under all ecological conditions, while Slate Black+ (14C6) was observed at high temperature under crowded condition.

Lateral view

(a) Head

Cloudy Amber (12K3) was observed at 27±1 °C under isolated condition. Ship skin Moth+ (11C3) was observed in the rest of the ecological conditions. There were no marked differences in the colour of compound eye with varied ecological conditions. Colours of the dots observed were similar as mentioned above in dorsal view of head.

(b) Pronotum

The ground colour observed was Bronze Clair (13D2) at 27±1 °C under both isolated and crowded conditions. Same observation was made in 37±1 °C and isolated conditions. Colour of dots was more or less similar to that of the dorsal view of pronotum.

(iii) III rd Instar Hoppers

Dorsal view

(a) Head

OLIVE GREEN (15L4) and Metallic Green ^{T} (15L6) were observed at 27±1 °C and 37±1 °C respectively. No mark difference in colour was observed under crowded and isolated conditions. Also there were no changes in the colour of streaks under any ecological condition, since GRAPHITE+ (48C7) was observed under all studied ecological conditions.

(b) Pronotum

Roman Green (15L5) was observed at 27±1 °C while Serpentine (14K3) was observed at 37±1 °C as ground colour under isolated as well as crowded conditions. Streak were uniformly limestone (15A4), under all ecological combinations, similarly colour of dots were also uniform.

Lateral View

(a) Head

Two different ground colours were observed at 27±1 °C, both under crowded and isolated conditions. But at high temperature similar colour (Sallow-12E2) was observed, under crowded and isolated conditions. Colour of compound eye was similar, both at high and low temperature under crowded and isolated conditions. Similar observation was made at 37±1 °C under crowded condition, which change to Sirocco (14B2) under crowded condition.

Two different colours, Hay–12I2 and ACRON–15E7, were observed under crowded and isolated conditions at same temperature (27±1 °C). Similar observations were made under crowded and isolated conditions, at high temperature (37±1 °C).

(b) Pronotum

Two slightly different colours, Oliveshen–13K3 and Cloudy Amber 12K3, were observed at 27±1 °C under crowded and isolated conditions, but at high temperature colourwas comparatively darker than the low temperature. Colour of dots on the head and pronotum was similar as observed under dorsal view for the same instar.

(iv) IV th Instar Hoppers

Dorsal View

(a) Head

Different ground colours were observed at two different temperatures, but similar colour was observed under crowded and isolated conditions at same temperature. Similar observations were made for streaks and dots.

(b) Pronotum

Ground colour was similar at low temperature, Acacia (11K1), both under crowded and isolated conditions. Slight darker ground colour was observed at high temperatures under crowded condition. Colour of streaks was similar under all ecological combinations, except at high temperature under crowded condition, and observed colour was Army Br (6A10). Colour of dots was slightly darker at high temperature under crowded and isolated conditions.

Lateral View

(a) Head

A gradient of colour changes was observed at all above experimental conditions. At low temperature, colour was less prominent, while at high temperature it was dark. Two different colours of streaks were found at low temperature, but at high temperature same colour was observed under both crowded and isolated conditions. Two different colours were observed at 27±1 °C, under crowded and isolated conditions. Similar observations were made at high temperature with slightly intensified under crowded condition. Colour of compound eye was similar, Manon (6A9), at low temperature and at high temperature under isolated condition. Slightly darker colour was observed at high temperature under crowded condition.

(b) Pronotum

Ground colour observed at low temperature was sheepskin Moth+(11C3), under both crowded and isolated conditions, while Cloudy Amber (12K3) was observed at 37±1 °C. Colour of Streaks

was found uniformly, except at high temperature under crowded condition. Colour of dots observed was similar to that of the dorsal side of pronotum.

(v) Vth Instar Hoppers

Dorsal View

a) Head

Two different ground colours were observed at low temperature, while at high temperature prominent but similar colour was observed under both crowded and isolated conditions. Colour of streaks observed was Moose (8C10) under each experimental condition, except at low temperature and isolated condition. Colour of dots was uniformly Slag (48A4) under all above combinations.

b) Pronotum

Two different colours (Roman Gr–15L5 and CITRINE–14L6) were observed at low temperature and under isolated and crowded conditions. Colour changes were not observed at 37±1 °C under crowded and isolated conditions. Colour of streaks was different at two temperatures, but similar, under crowded and isolated conditions. Colour of dots (Brownzesheen–12J5) observed was uniform under all said combinations.

Lateral View

(a) Head

The ground colour observed was Prairie+ (13F6) at low temperature under crowded conditions and also at high temperature under both crowded and isolated conditions. Colour of streaks observed were Pelt (15C4) at high temperature under crowded and isolated conditions. Similar colour was observed at 27±1 °C, only under crowded conditions. Colour of dots observed was SUNSET (10C4) under most of the combinations except at low temperature and isolated condition. Colour of compound eye was slightly intense at high temperature under crowded condition, while under rest of conditions; similar colour (LIGHT STONE–12J5) was observed.

(b) Pronotum

Two different ground colours were observed at two different temperatures, but similar colour was observed under isolated and crowded condition at each temperature. Colour of streaks observed was mainly SUNSET (10C4). Colour of dots observed was similar to that of pronotum.

(vi) Adult Male

Dorsal View

(a) Head

Similar ground colour was observed at low temperature, under crowded and isolated conditions, but two different colours were observed at 37±1 °C under crowded and isolated conditions. Colour of streaks observed was Hair Brown (15A4) at low temperature under crowded condition and also at high temperature under both isolated and crowded conditions. Colour of dots was uniform under all each conditions.

(b) Pronotum

Two different colours, Brown Surger (15H11) and Bronze Brown (16C9), were observed at low temperature under isolated and crowded conditions, similar colour was observed at 37±1 °C under both isolated and crowded conditions. Colour of streaks was similar to that of the head. Two slightly different colours, BURNET UMBER^{P}-15A12 and COCOA BROWN+, were observed at 27±1 °C and 37±1 °C respectively.

Lateral View

(a) Head

The ground colour observed was BEAVER (15A6) at 27±1°C, but slightly darker colour (OLD GOLLD–14K5) was observed at 37±1 °C under crowded condition. Colour of streaks observed were SEAL (8E10) at low temperature, under both isolated and crowded conditions; Java Brown (8J8) was observed at high temperature under crowded condition. Colour of dots was similarly observed in dorsal view of head. Colour of compound eye observed was Bronze Clair (13D2) under all experimental conditions, except at low temperature and isolated condition.

(b) Pronotum

Two different ground colours were observed at two different temperatures, further difference in colour was observed under isolated and crowded conditions. Colour of streaks observed was similar to that of head and colour of dots were as observed under dorsal view of pronotum.

(vii) Adult Female

Dorsal view

(a) Head

Ground colour observed was similar at 27±1 °C under isolated and crowded conditions, but two different ground colours were observed at 37±1 °C under isolated and crowded conditions. Two different colours, NED COCOA–7A10 and VANDYKE BROWN, were observed at low temperature under isolated and crowded conditions, but similar and intense colour (Cameo–6F9) was observed at high temperature, both under isolated and crowded conditions. Two different colour of dots was observed at low and high temperature, both under isolated and crowded conditions.

(b) Pronotum

The ground colours observed were less prominent at low temperature under isolated condition than the high temperature. Colour of streaks observed was similar at low temperature, but at high temperature two different colours were observed under isolated and crowded conditions. Colour of dots observed was more or less similar both at low and high temperatures, under both isolated and crowded conditions.

Lateral view

(a) Head

Two different ground colours were observed at low and high temperatures, both under isolated and crowded conditions. Colour of streaks observed at high temperature was darker than at low temperature. Colour of dots was similar to those on dorsal side of head. Colour of compound eye observed was darker at high temperature as compared to low temperature.

(b) Pronotum

Similar ground colour was observed at low temperature under crowded condition and also at high temperature under both isolated and crowded conditions. Colour of streaks and dots were similar as observed under dorsal view of pronotum.

II. Description of colour patterns in *Oedaleus abruptus*

(i) Ist Instar Hoppers

Dorsal View

(a) Head

The ground colour observed at low temperature was Italian Straw (11D2) and Mustard (11J4) under isolated and crowded conditions. The ground colour observed at high temperature was similar as observed at 27±1 °C under crowded condition. The colour of post ocular patch was similar under all ecological conditions.

(b) Pronotum

Similar ground colour, BUFE (11K7), was observed at low temperature under both isolated and crowded conditions. Similarly, Laurel oak (7J10) was observed at high temperature under both isolated and crowded conditions. Colour of mid dorsal region observed was green OLIVE GREEN (15L4) at low temperature and Beech (15E4) at high temperature respectively.

Lateral View

(a) Head

The ground colour observed was uniformly Hay (12I2). Streaks haven't appeared and dark spots (dots) were less pronounced among Ist Instar hoppers.

(b) Pronotum

Change in ground colour was not observed while streaks and dots were fewer and less prominent.

(ii) IInd Instar Hoppers

Dorsal View

(a) Head

The ground colour observed was uniformly Glass Gr. (18D3) under all ecological conditions except at high temperature under crowded condition. Two different colours of post ocular patch observed were Rubber (15H8) and Bison– (16A10). Colour of dots were similar as observed in Ist instar.

(b) Pronotum

Two different ground colours, OLIVE WOOD (15E10) and Elk Lama– (16A11), were observed at two different temperatures and under isolated and crowded conditions. Similarly two different colours of mid dorsal region were observed under said conditions. Colour of dots and its frequencies were similar as observed in Ist Instar.

Lateral View

(a) Head

The ground colour observed was uniformly Turtle Gr. (19G5) except at low temperature and under isolated condition. Colour of streaks was less prominent and uniformed Cub (15C1) under all ecological conditions. Colour of dots was similar as observed under dorsal view of head. The colour of compound eye observed was an Oyster Gy (19A2) under all ecological conditions.

(b) Pronotum

Two different ground colours, Amber white (11C1) and English Grey (15C2), were observed at two different temperatures under both isolated and crowded conditions. Colour of streaks observed was uniformly Shadow Green (20J3) under all ecological conditions. No change was observed among dots.

(iii) IIIrd Instar Hopper

Dorsal view

(a) Head

The ground colour observed was uniformly OCEAN GR (18B5) except at low temperature under isolated condition. The colour post ocular patch observed at low temperature was Chipmunk (13L9) while at high temperature it was observed as tortoise shell (14G11), similar colour was observed at low temperature under crowded condition.

(b) Pronotum

Two different colours were observed as Mustard Br+ (14D10) and Cognae (14J11) at low temperature under isolated condition and at high temperature under both isolated and crowded conditions. Colour of mid dorsal region was slightly darker at 37±1 °C under both isolated and crowded conditions. Colour of dots was similar as mentioned in IInd Instar but it was more prominent in given instars.

Lateral view

(a) Head

The ground colour observed was darker at 27±1 °C under crowded conditions and at 37±1 °C under both isolated and crowded conditions. Colour of streaks was uniformly Cub (15C1) under all ecological conditions. Colour of dots and

magnitude of intensity were similar as observed under dorsal view of head.

(b) Pronotum
The ground colour was almost similar under all ecological conditions except at high temperature under crowded condition, which is slightly darker (SMOKE BROWN-16A2). Colour of streaks was uniformly Corydalis Gr. (19B4) under all ecological conditions. Colour of dots was similar as observed under dorsal view of pronotum.

(iv) IVth Instar Hopper
Dorsal view
(a) Head
Influence of crowded condition was not observed but an effect of temperature was prominent for ground colour. Colour of post ocular patch observed was similar under all ecological conditions. No marked differences were observed among dots as compared to the last instars.

(b) Pronotum
Two different ground colours were observed at two different temperatures under both isolated and crowded conditions. The ground colour was darker at high temperature. Colour of mid dorsal region observed was PEA GREEN (20J6) except at low temperature under isolated condition.

Lateral view
(a) Head
Two different ground colours observed were, Fern Gr (21A5) and Mignon Gr (21J6), at low temperature under isolated condition and at same temperature under crowded condition. Similar colour was observed at high temperature under isolated and crowded conditions. Colour of streaks observed was more or less similar under all ecological conditions. Slightly dark colour of compound eye was observed at high temperature under both isolated and crowded conditions.

(b) Pronotum
The ground colour observed was Rodent (16C3) at low temperature under isolated and crowded conditions, similar colour was observed at high temperature under isolated condition, but at high temperature colour get intensified. Two different colours of streaks were observed at two different temperatures but influence of crowded condition was not observed. Mostly coarse dots were observed through out the body.

(v) Vth Instar Hopper
Dorsal view
(a) Head
Two different colours were observed at two different temperatures, slightly darker at high temperature. Influence of crowded condition was not observed on the colour of post ocular patch but effect of temperature was prominent at two different temperatures. Mostly coarse dots were observed.

(b) Pronotum
Two different ground colours were observed at 27±1 °C, but similar colour was observed at 37±1 °C under both isolated and crowded conditions. Similar observations were made in case of mid dorsal region. Size and colour of dots were similar as above.

Lateral view
(a) Head
The ground colour observed was Mignon Gr. (21J6) at low temperature under crowded conditions and also at high temperature under isolated and crowded conditions. The ground colour was less prominent at low temperature under isolated condition. Colour of streaks was uniform under most of the conditions except at low temperature under isolated condition. Colour of compound eye observed was Hemp (14H4) at 27±1 °C but two slightly darker and different colours were observed at 37±1 °C under isolated and crowded conditions.

(b) Pronotum
Influence of two different temperatures was observed for ground colours, but effect of crowded condition was not prominent. Colour of streaks found to be darker at high temperature under crowded conditions.

(vi) Adult Male
Dorsal view
(a) Head
Both, affect of temperature and crowded condition were observed on the ground colour, thus gradient of colours were observed at two temperatures under both isolated and crowded conditions. Colour of post ocular patch observed was Grasshopper (20F6) under all ecological conditions. Very few dots remain at adult stage in the specific areas of integument.

(b) Pronotum
The ground colour observed at high temperature was more prominent than at low temperature. Colour of mid dorsal region doesn't show much difference under any ecological conditions.

Lateral view
(a) Head
Two different ground colours were observed at two temperatures, but influence of crowded condition was not observed. Similarly colour of streaks was more or less same at two temperatures with no influence of crowded condition. Colour of compound eye observed was similar at low temperature under isolated and crowded conditions. While two different colours were observed at high temperature.

(b) Pronotum
Effect of temperature was more pronounced for ground colour than the crowded condition, which is negligible for both temperatures. Two different colour of streaks was observed at two temperatures, later was prominent and darker.

(vii) Adult Female
Dorsal view
(a) Head
Different ground colours were observed under different ecological conditions is indicative of the influence of both temperature and crowded condition. Colour of post ocular patch observed was similar at low temperature, but two different colours were observed at high temperature under isolated and crowded conditions, which suggest the influence of crowded conditions. Dots were negligible under all conditions.

(b) Pronotum
The ground colour observed was almost similar under all ecological conditions except at low temperature under isolated condition. Colour of mid dorsal region observed was different under all ecological condition. Effect of both temperature and crowded condition were prominent. Number of dots and its colour were similar as observed in male.

Lateral view
(a) Head
Two different ground colours were observed at high and low temperatures, but effect of crowded conditions was not prominent. Colour of streaks observed was similar with exception at low temperature under isolated conditions.

(b) Pronotum
Two different ground colours were observed at two different temperatures, again effect of crowded condition was not observed. Colour of streaks was similar at high temperature but two different colours were observed at low temperature.

4. Result and Discussion
Both grasshoppers exhibited wide range of colour patters under stress of different experimental conditions. Bold patterns mainly dark brown and black colours were observed at high temperatures under crowded condition in case of *Phlaeoba infumata*, while in case of *Oedaleus abruptus* ground colour varied from green to brown. Other components like dark spots and streaks also exhibited considerable variation under stress of different experimental conditions. Biologically, the most important difference between the crowded and isolated population was higher activities and tendency of aggregation characterised by higher feeding potential and band formation at high temperature under crowded condition. Bold patterns mainly dark brown and black colours were observed at high temperatures under crowded condition.

5. Conclusion
These observations clearly indicated that both the species are having distinct behaviour of gregarization, swarm forming tendency and having ability of mass active behaviour with local migratory instincts. These observations are the substantial addition to the knowledge of polymorphism in acridoids.
On the basis of the present studies it can convincingly be concluded that the species under study are very aggressive in behaviour, can assume new dimensions of behaviour and may become gregarious and migratory under favourable ecological conditions and may cause losses to agricultural crops and medicinal plants with greater potential after the formation of swarm and as they are polyphagous in nature.

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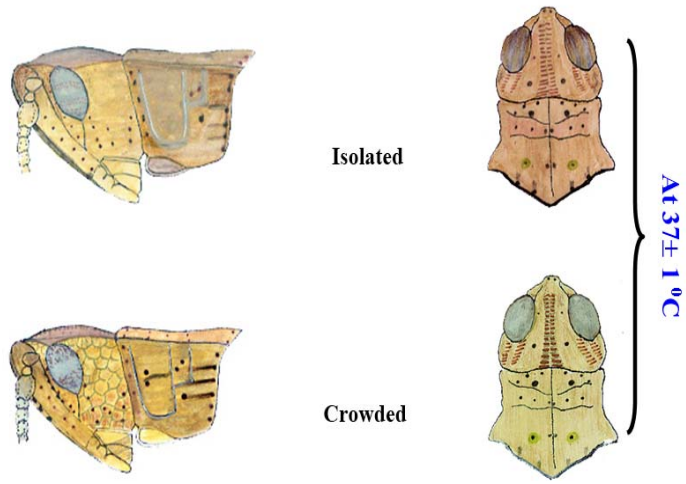


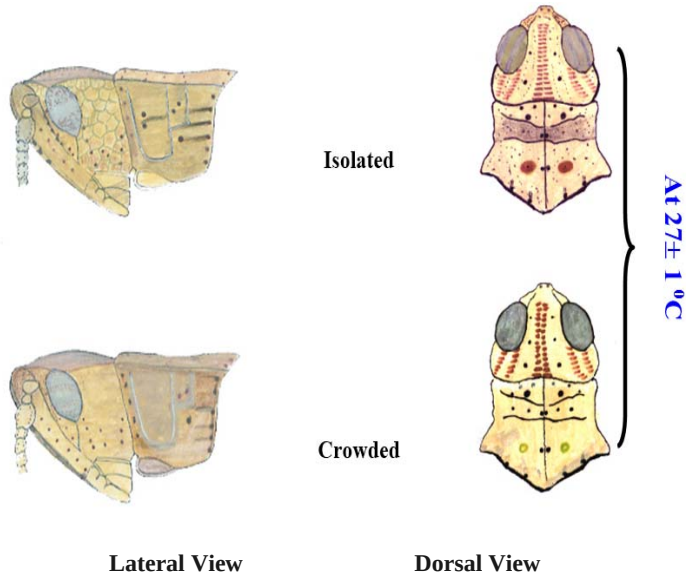


Plate 1: *Phlaeoba infumata* – Ist Instar (Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions

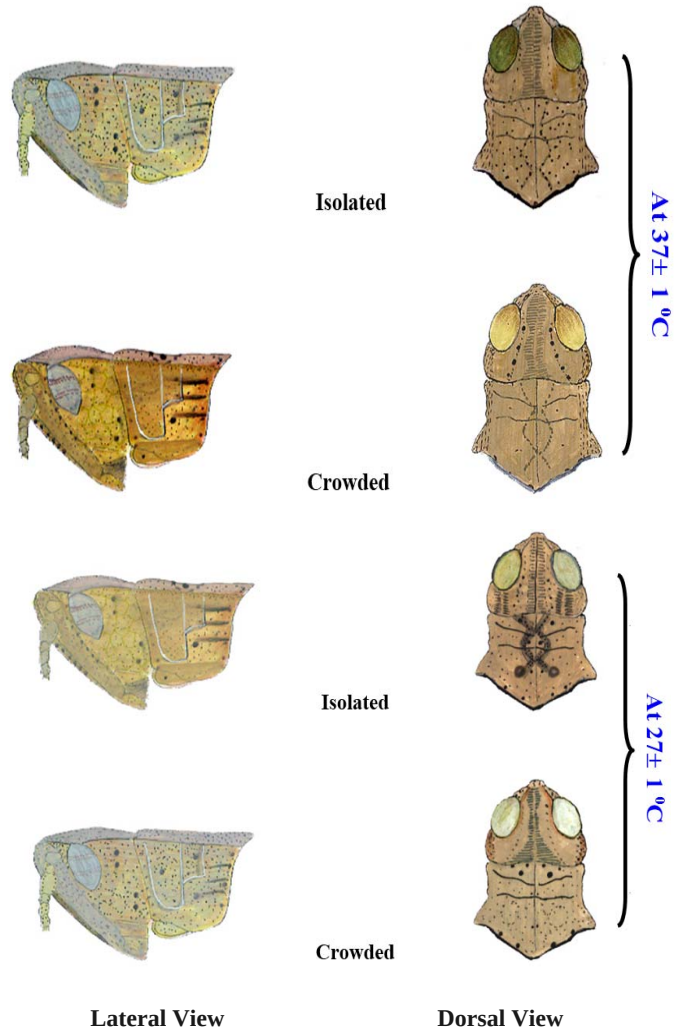


Plate 2: *Phlaeoba infumata* – IInd Instar (Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions

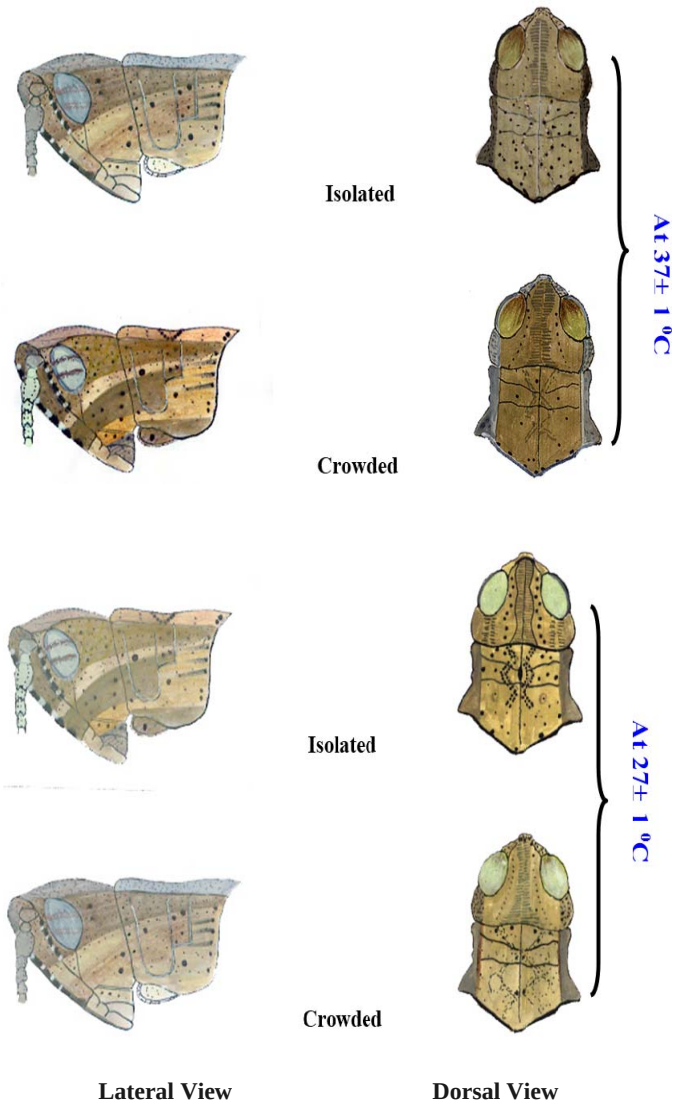


Plate 3: *Phlaeoba infumata* – IIIrd Instar (Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions

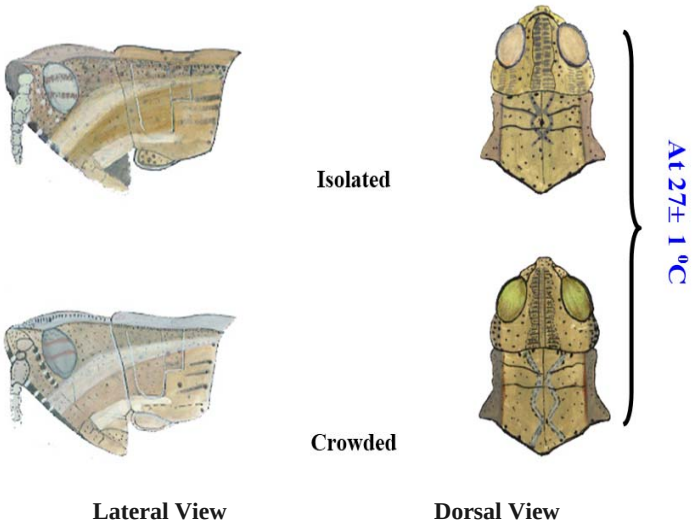


Plate 4: *Phlaeoba infumata* – IVth Instar (Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions

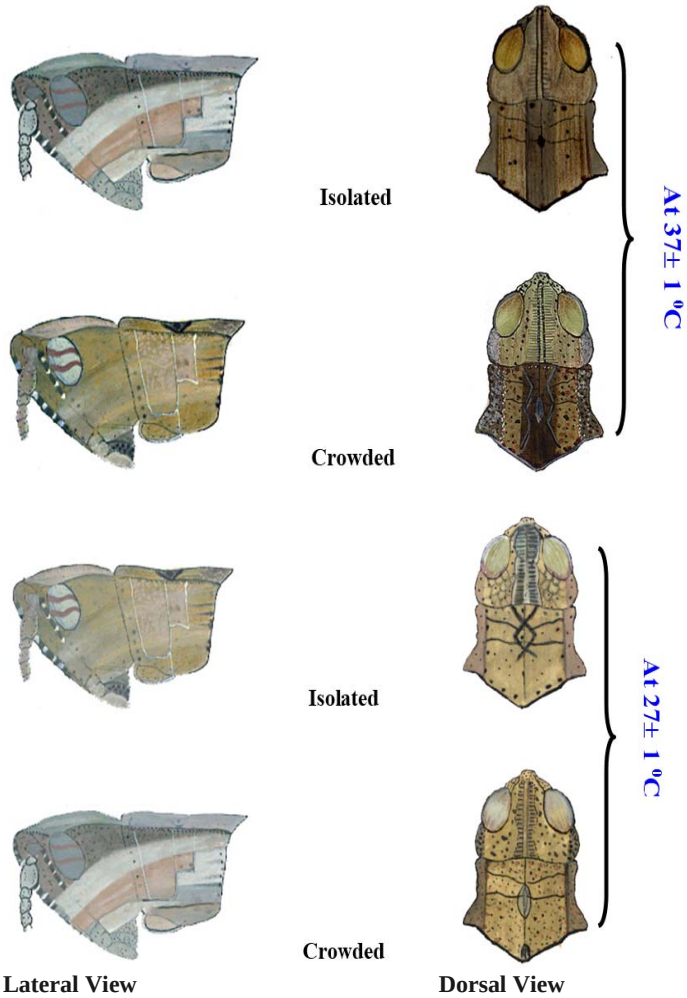
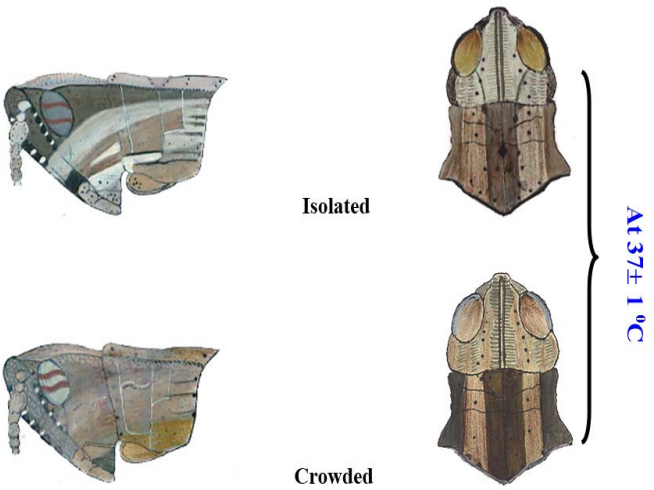


Plate 5: *Phlaeoba infumata* – Vth Instar (Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions



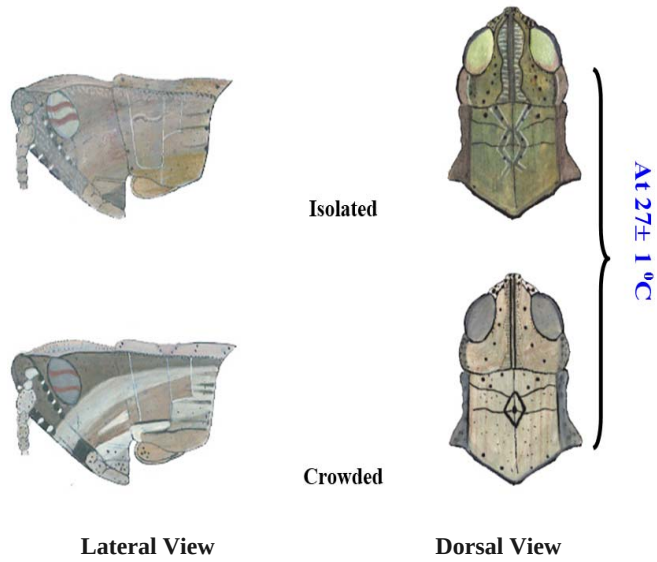
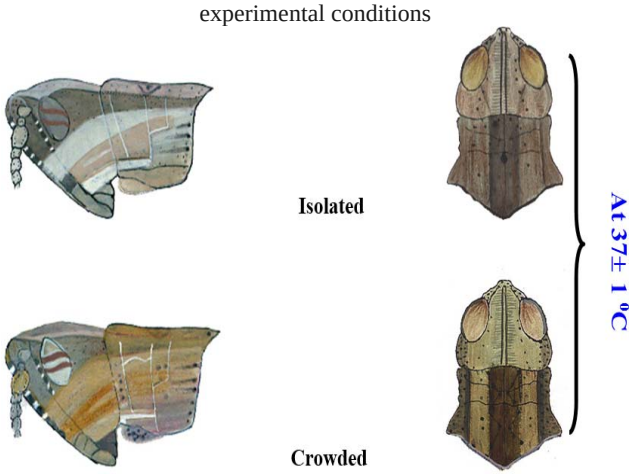


Plate 6: *Phlaeoba infumata* – Female (Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions



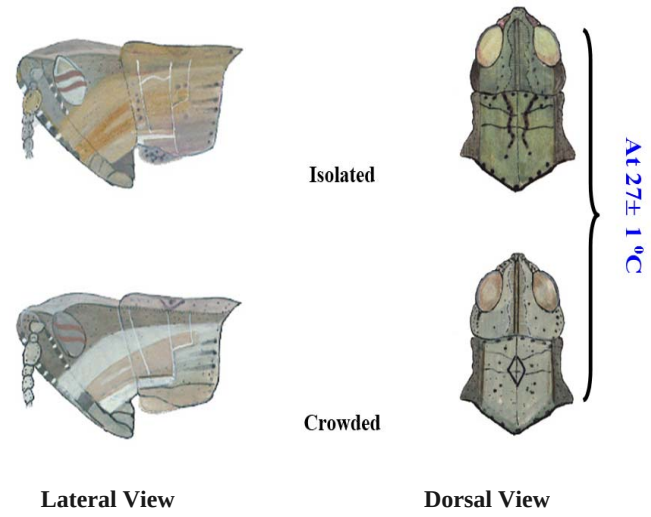


Plate 7: *Phlaeoba infumata* – Male (Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions

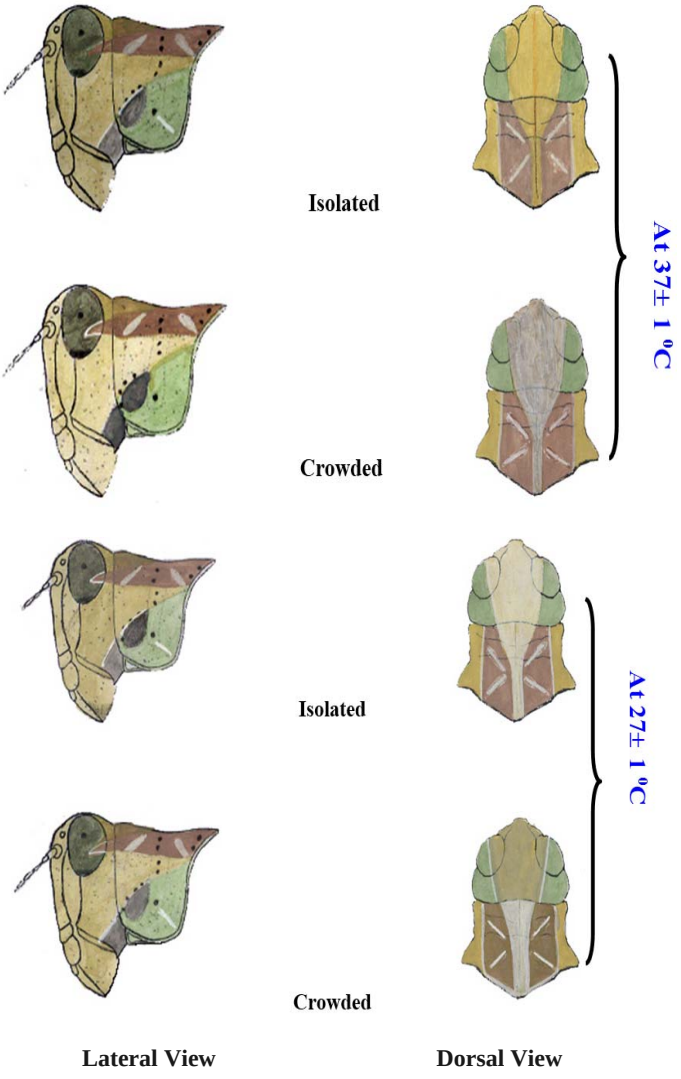


Plate 8: *Oedaleus abruptus* – Ist Instar (Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions

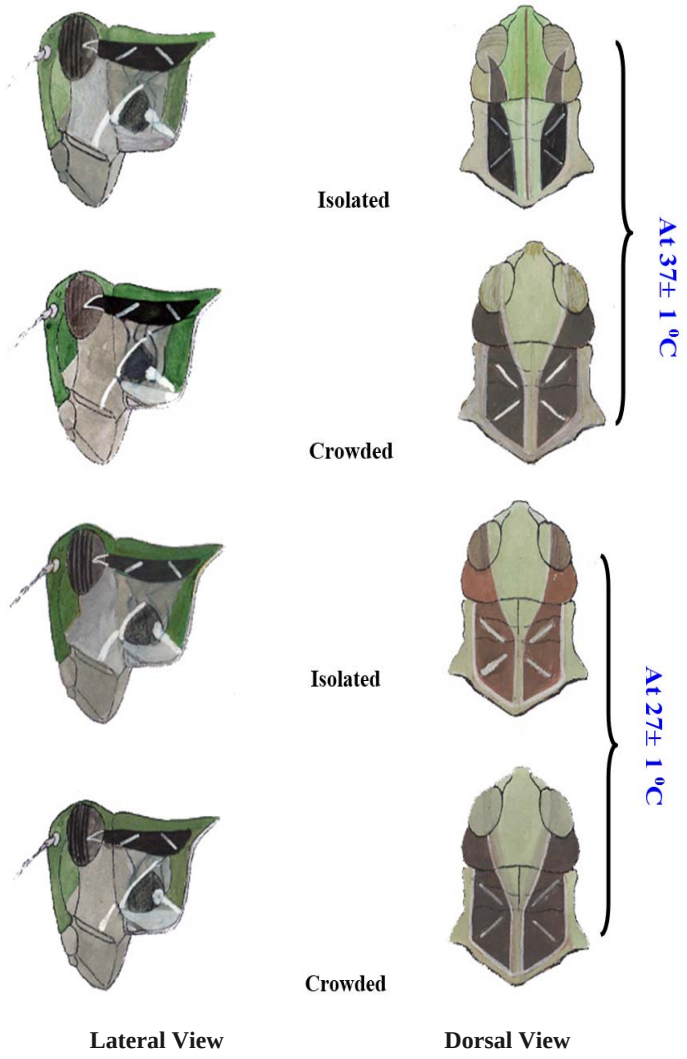
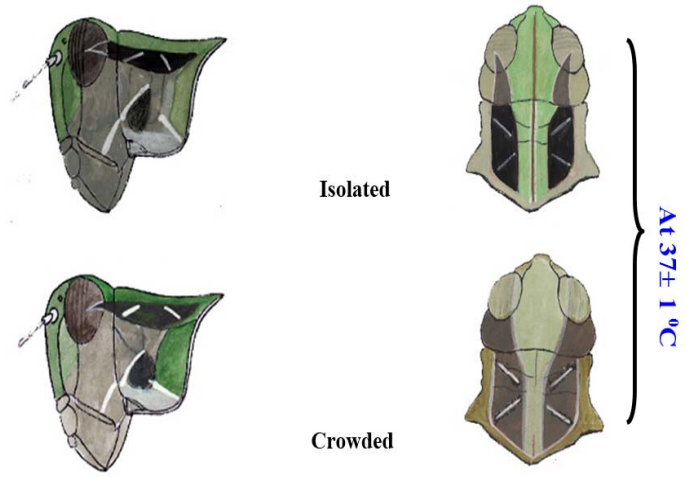


Plate 9: *Oedaleus abruptus* – IInd Instar (Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions



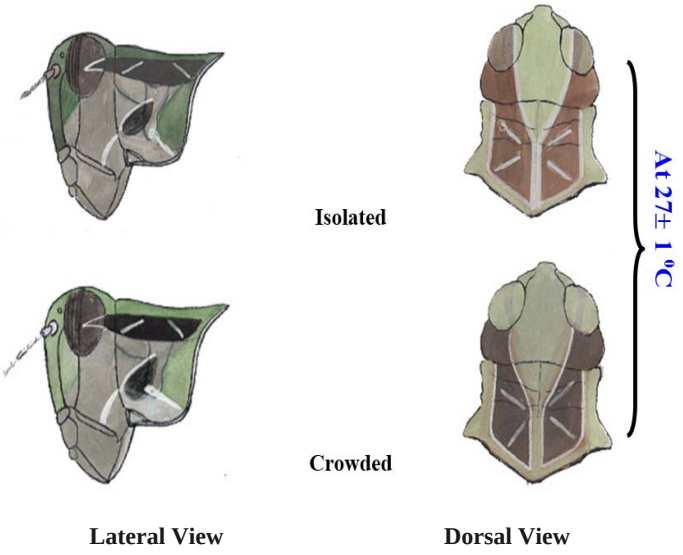


Plate 10: *Oedaleus abruptus* – IIIrd Instar (Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions

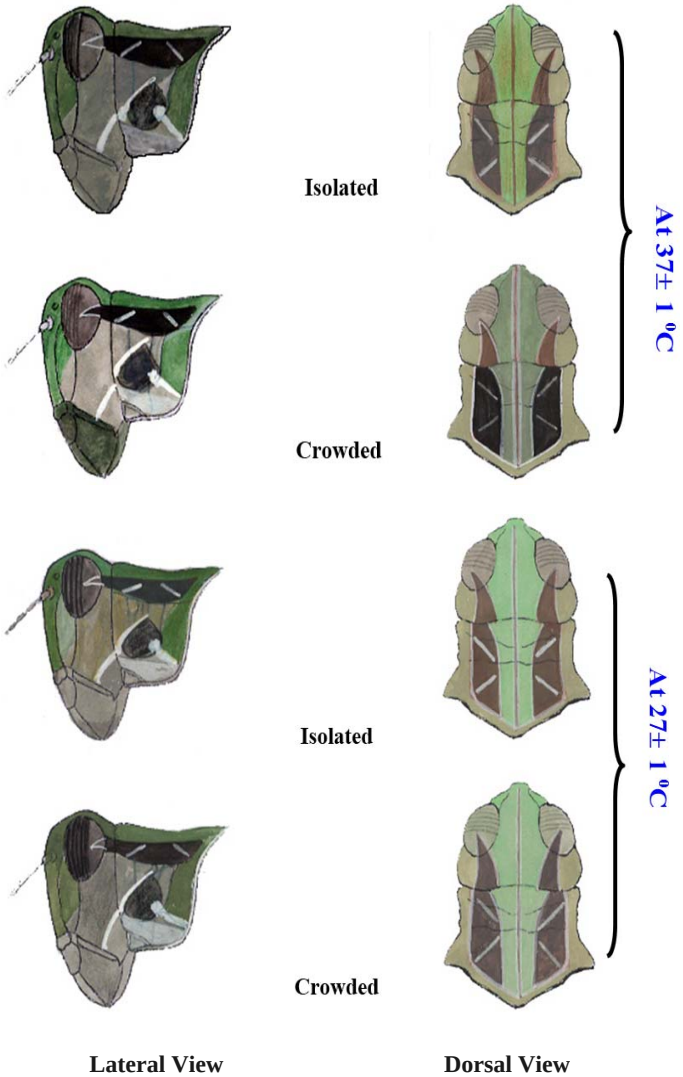


Plate 11: *Oedaleus abruptus* – IVth Instar (Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions

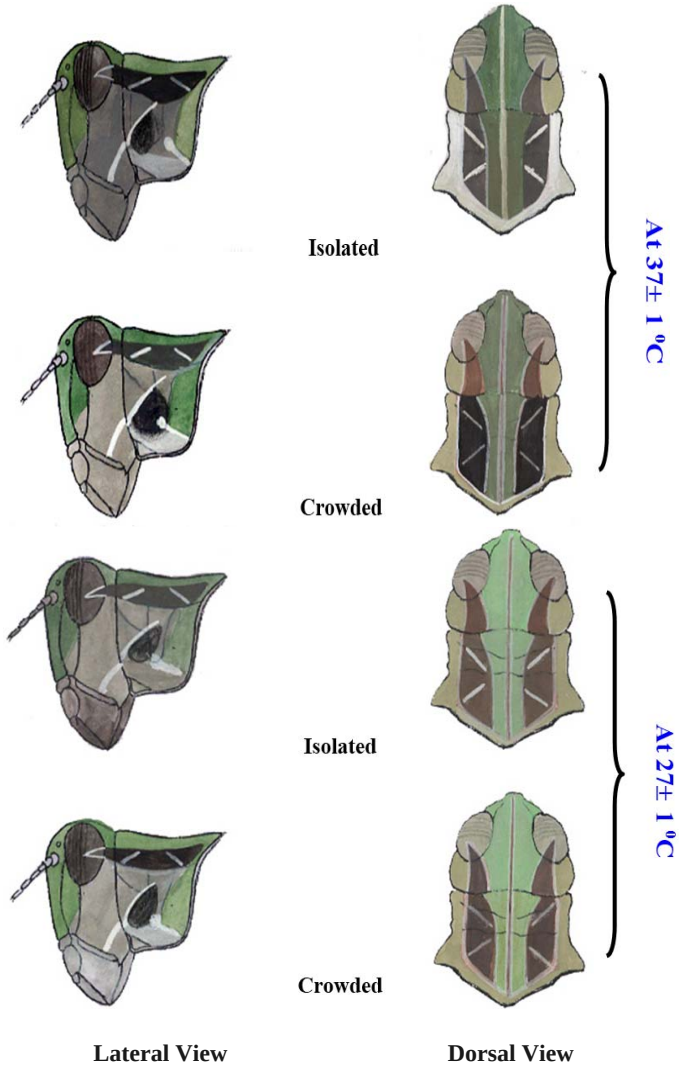
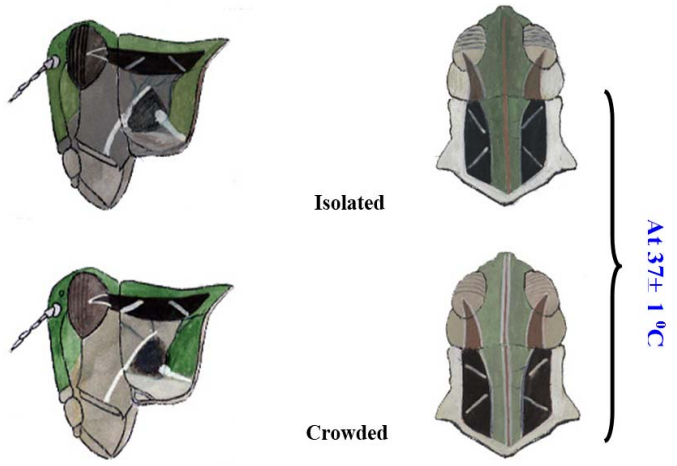


Plate 12: *Oedaleus abruptus* – Vth Instar (Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions



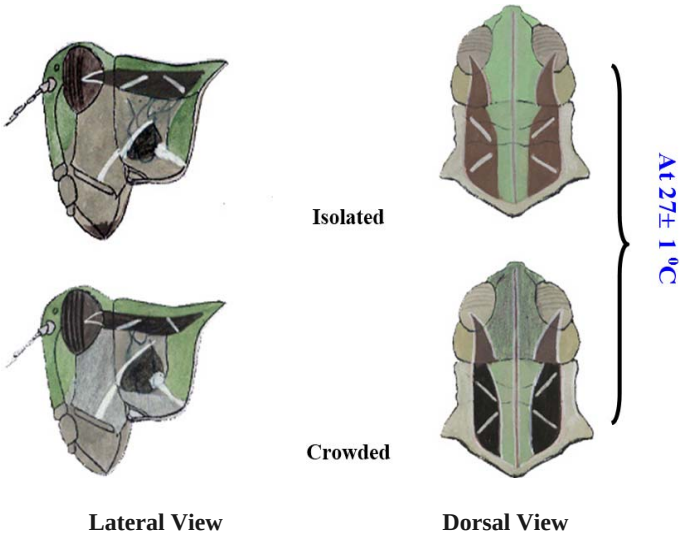


Plate 13: *Oedaleus abruptus* – Female (Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions

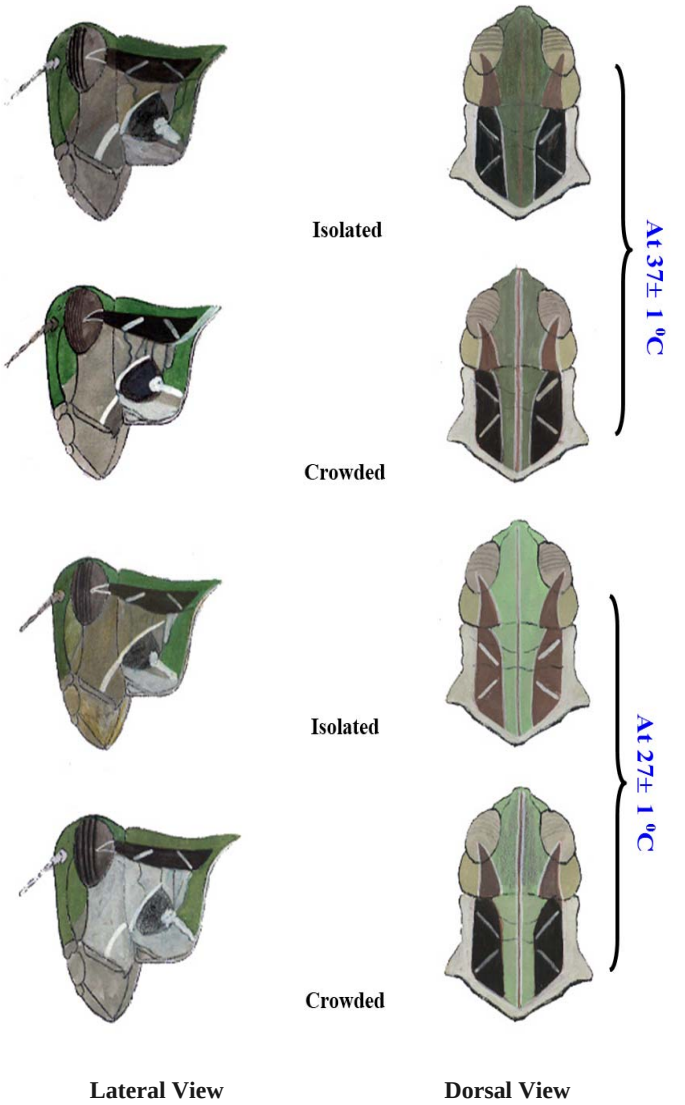


Plate 14: *Oedaleus abruptus* – Male **(**Dorsal and Lateral views of Head and Prothorax) showing colour changes under different experimental conditions.