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NEUROENDOCRINE SYSTEM AND ROLE OF DORSAL AORTA AS A NEUROHAEMAL ORGAN IN A HETEROPTERAN BUG BAGRADA CRUCIFERARUM *KIRK. (HETEROPTERA : PENTATOMIDAE)*

BY

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ABSTRACT. — *5 A-type medial neurosecretory cells (NSC) are present in each brain hemisphere. Lateral and medial B-cells are absent. The suboesophageal ganglion has 2 A-type NSC. The other ganglia of ventral nerve cord lack these cells. PF-positive neurosecretory material (NSM) is stored in the dorsal aorta and paired corpora cardiaca lack NSM.*

Key words : Neurosecretory cells, neurosecretory material, neurohaemal organ, dorsal aorta, corpora cardiaca, *Bagrada cruciferarum.*

INTRODUCTION

A perusal of the literature on the neuroendocrine system reveals a neurohaemal nature of the dorsal aorta in most heteropteran insects (JOHANSSON, 1957, 1958; SESHAN and ITTYCHERIAH, 1966; DOGRA, 1967*c*, 1969; AWASTHI, 1972, 1973*a*, *b*; SRIVASTAVA, 1970; FURTADO, 1971; TIWARI and SRIVASTAVA, 1975; TIWARI *et al.*, 1975 and SINGH and NARAIN, 1980). However, there are certain exceptions like *Adelphocoris lineolatus* (EWEN, 1962*b*) and *Dysdercus similis* (GUPTA, 1970) where it has been reported that corpora cardiaca (CC) act as neurohaemal organs (NHO). In *Iphita limbata*,

although, NAYAR (1956, 1957) has reported that neurosecretory material (NSM) is stored in CC, reinvestigations of SESHAN and ITTYCHERIAH (1966) in the same insect have found that NSM is stored in the aorta wall and not in CC. In *Lethocerus indicum*, DOGRA (1969) reported the dorsal aorta to be a NHO. On the other hand, BHARGAVA (1970, 1972) in the same insect suggested the CC to be the storage and release organ of the NSM. In *Rhodnius prolixus*, WIGGLESWORTH (1964) conclusively reported that the CC performed the function of NHO, whereas, in the same insect FARUQUI (1977) reported a portion of CC, fused with aorta, serving this function, thus representing a transitional stage between the typical insect and the heteropteran conditions.

The object of the present investigation is to collect more information about the neurohaemal nature of the aorta in Heteroptera. This report deals with the neuroendocrine system of *Bagrada cruciferarum* with special reference to the dorsal aorta as NHO.

MATERIALS AND METHODS

Nymphs and adults of *B. cruciferarum* were collected locally and were reared in the laboratory on mustard leaves. Bouin's solution was injected in the adult insects prior to dissections. Dissections were done under a stereoscopic binocular microscope. The brain, nerve cord and retrocerebral endocrine-aortal complex were taken out and fixed in aqueous Bouin's fixative for 18-24 h and bulk staining of these organs with paraldehyde Fuchsin technique (EWEN, 1962*a*) was done to locate the NSM. Paraffin blocks of some of these fixed materials were made. These blocks were cut at 6-8 μm thick and stained by the above technique.

OBSERVATIONS

The neurosecretory and neuroendocrine systems of both sexes resemble completely. The whole system is almost bilaterally symmetrical except for corpus allatum which is medially placed and single.

A. *The neurosecretory cells of the brain.* — A group of 5 A-type NSC are present in each brain hemisphere over the anterodorsal

part of the pars intercerebralis medialis region of the protocerebrum. These cells are more or less oval in shape and measure about 25 × 18.25 μm (Fig. 1). Secretory inclusions of these cells stain deep purple with PF stain (Fig. 2). These cells possess centrally placed nuclei. Granules of NSM are distributed uniformly throughout the cytoplasmic areas of the cells. The NSM is compactly packed in the cells of individuals undergoing mating. At a particular time majority of the cells exhibit similar phase of secretory activity (Figs. 2-4). The lateral and median B-type NSC are absent in this insect.

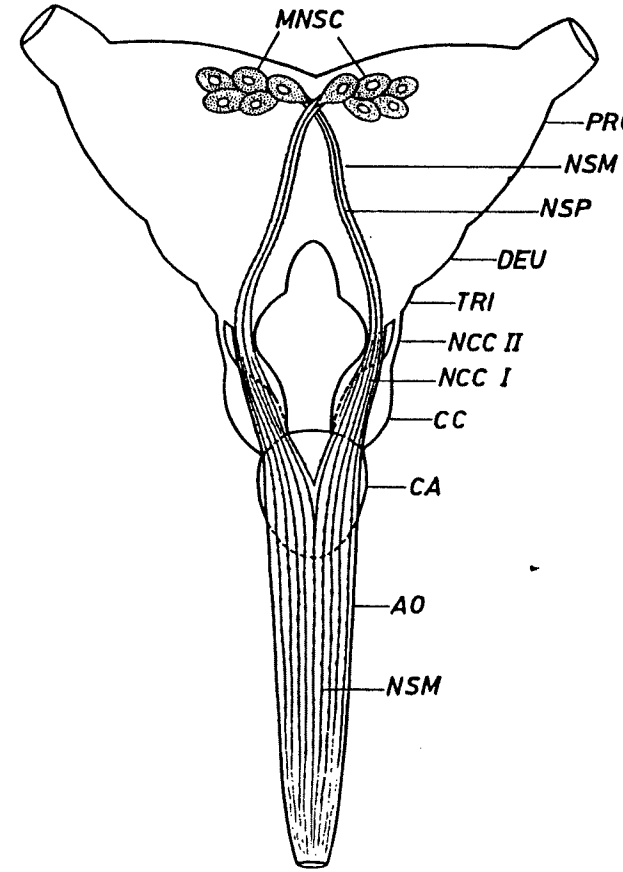

FIG. 1. Diagram of the neurosecretory system of *B. cruciferarum* showing aorta (AO), corpora cardiaca (CC), deutocerebrum (DEU), median neurosecretory cells (MNSC), nervi corporis cardiaci I (NCC I), nervi corporis cardiaci II (NCC II), neurosecretory material (NSM), neurosecretory pathways (NSP), protocerebrum (PRO), tritocerebrum (TRI).

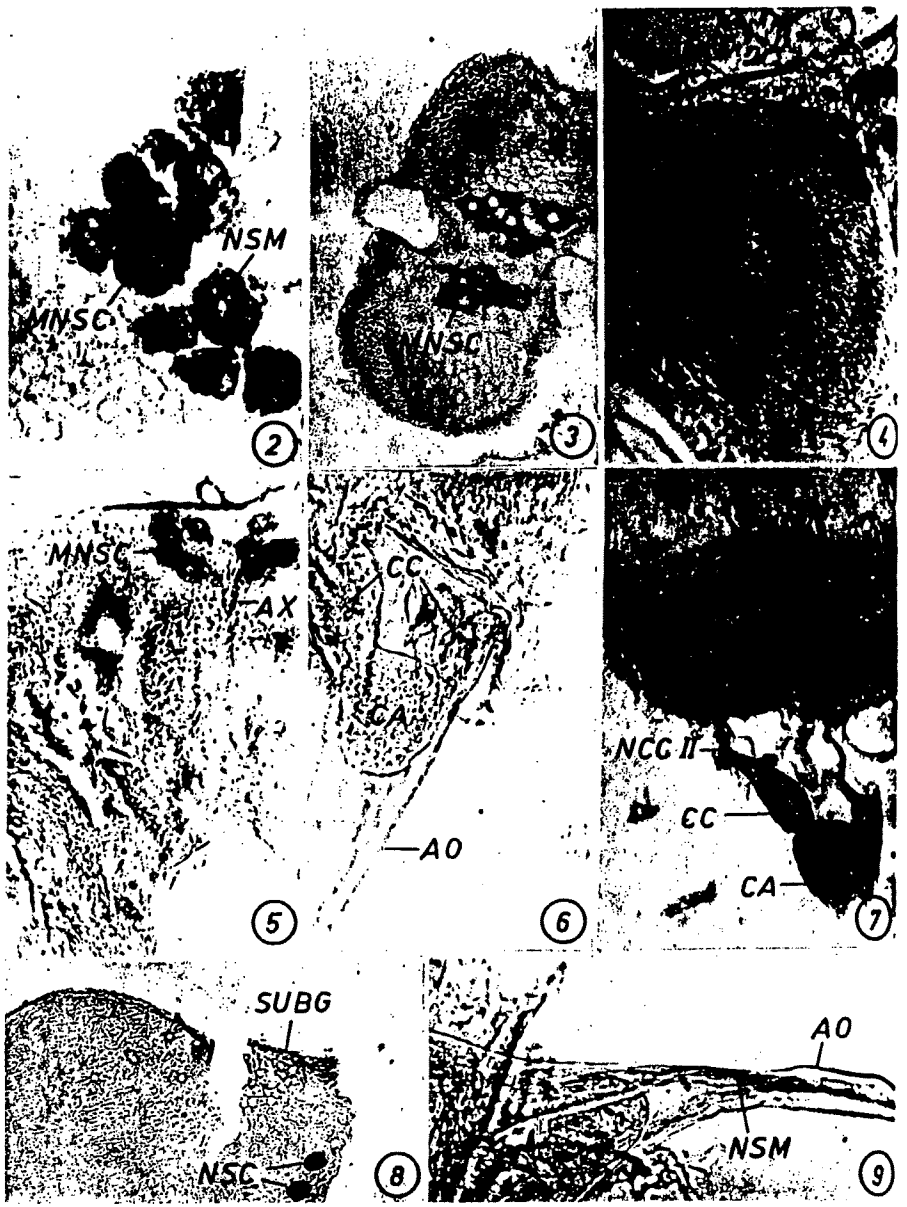

FIG. 2. F.S. brain of male just after mating showing median neurosecretory cells (MNSC) packed with neurosecretory material (NSM). ×450.

FIG. 3. F.S. brain of male after mating showing MNSC. ×200.

FIG. 4. W.M. brain of male during mating showing large amount of NSM in MNSC. ×200.

B. *The neurosecretory cells of the ventral nerve cord.* — Very close to the ventral surface of the suboesophageal ganglion, two oval A-type NSC are present (Fig. 8). These are similar to but smaller than the cerebral NSC (18.25 × 12.5 μm). The prothoracic and fused mesothoracic ganglionic mass lack NSC.

C. *The medial neurosecretory pathways and nervi corporis cardiaci I (NCCI).* — Axons of each group of medial NSC converge and form a medial neurosecretory pathway (Fig. 1, 5). Two such medial neurosecretory pathways thus formed run a little on the dorsal side and turn downwards to crossover each other. As the result of this crossing over, the position of the two pathways is changed. These axonal pathways thereafter pass through protocerebrum and deutocerebrum and finally emerge from the tritocerebrum as nervi corporis cardiaci I (NCCI). Each NCCI completely bypasses the corpus cardiacum and joins with the dorsal aorta from the latter's lateral side. The transport of the NSM through the medial neurosecretory pathways is clearly visible due to their strong positive reaction to the PF stain.

D. *The dorsal aorta.* — The dorsal aorta is situated dorsally to the retrocerebral endocrine glands and extends from the posterior region of the brain to the posterior end of the body (Fig. 6). Each NCCI is apposed with the aorta from its lateral side. The axons of NCCI spread all around the wall of the dorsal aorta and terminate at different levels. In the aorta wall, granules of NSM of various shapes and sizes show their presence from the point of association of the axons. It is so upto the anterior half of the dorsal aorta. The axons of the NCC I in aorta wall of mating individuals are heavily loaded with NSM (Fig. 9). The aortal NSM stains similar to that of the medial A-cells which suggests that the NSM elaborated by the medial A-cells is stored in the dorsal aorta.

FIG. 5. W.M. brain of male during mating showing MNSC and neurosecretory axons (AX). ×200.

FIG. 6. W.M. of retrocerebral endocrine - aortal complex of female during mating showing corpora cardiaca (CC), corpora allata (CA) and aorta (AO). ×200.

FIG. 7. F.S. brain alongwith CC and CA of laid female showing nervi corporis cardiaci II (NCC II). ×200.

FIG. 8. L.S. of ventral nerve cord of laid female showing two neurosecretory cells (NSC) only in the suboesophageal ganglion (SUBG). ×200.

FIG. 9. W.M. of retrocerebral endocrine - aortal complex of male during mating showing the presence of NSM in the AO. ×200.

Variations in the amount of NSM are seen in different specimens. The posteriormost part of the aorta lacks NSM. It indicates that the anterior half of the aorta is responsible for the storage and release of the NSM and acts as a NHO.

E. *Nervi corporis cardiaci II (NCC II).* — From the tritocerebrum, two extremely short and thick nerves arise laterally to the NCC I and join with the corpora cardiaca of corresponding sides. These nerves are known as nervi corporis cardiaci II (Fig. 7). The lateral NSC are absent in *B. cruciferarum*, thus the intracerebral lateral neurosecretory pathways are absent.

F. *The corpora cardiaca.* — Corpora cardiaca are a pair of elongated to club-shaped structures lying on the dorsolateral surface of the oesophagus and ventrolateral to the aorta behind the brain. Each corpus cardiacum measures about 87.5 μm in length and 31.25 μm in breadth. The two CC never meet with each other but their posterior portions are directly attached with the median corpus allatum (Fig. 6). Histologically, corpora cardiaca consist of cells of various sizes which stain light green with the counter stain of PF-technique.

Corpora cardiaca never show any trace of NSM in bulk stained or histological preparations. It conclusively suggests that NSM elaborated in the medial A-cells is stored and released by the aorta and not by the CC.

G. *The corpus allatum.* — The corpus allatum (CA) is a single ovoid body situated on the dorsal side of the oesophagus and ventral to the aorta. It measures about 75 μm in length and 50 μm in breadth. The cells of the CA are similar to the cells of CC in shape and staining properties. PF-positive NSM is never observed in this organ in *B. cruciferarum*.

Discussion

The general morphology and histology of the neuroendocrine system of *B. cruciferarum* closely resemble that of the other heteropteran insects (Awasthi, 1972 and Singh and Narain, 1980). However, only A-type neurosecretory cells have been observed in this insect in contrast with the various cell types recognized by Nayar (1955), Johansson (1958), Ewen (1962*b*), Gupta (1970) and Singh and Narain (1980) in other heteropteran insects.

This parallels the observations of Dogra (1969), Awasthi (1972, 1973*a*) and Tiwari and Srivastava (1975).

Presence of NSC has been reported in various ganglia of the ventral nerve cord of Heteroptera. Johansson (1958) observed these cells in the prothoracic and fused mesothoracic ganglionic mass while Tiwari and Srivastava (1975) in *Dysdercus koenigii* found these cells in all the ganglia of ventral nerve cord. On the other hand Nayar (1955), Gupta (1970), Unnithan *et al.* (1971), Awasthi (1972, 1973*a*) and Singh and Narain (1980) reported the presence of these cells in the suboesophageal ganglion only. In *B. cruciferarum* only suboesophageal ganglion possesses two A-type NSC whereas other two ganglia are devoid of these.

The manner in which the neurosecretory pathways are formed in *B. cruciferarum* reveals conformity with the observations of the workers like Dogra (1967*a*, *b*), Awasthi (1972, 1973*a*, *b*) and Singh and Narain (1980). The two nerves (NCC I and NCC II) are separate and of different lengths in contrast with the observations of Cazal (1948), Benwitz (1956), Junqua (1956), Johansson (1958) and Ewen (1962*b*) who reported fused NCC. The PF-positive NCC I join with the dorsal aorta from its lateral side while NCC II (devoid of PF-positive NSM) join the corpora cardiaca of corresponding side.

Except in *Adelphocoris lineolatus* (Ewen, 1962*b*) and *Dysdercus similis* (Gupta, 1970), where it has been reported that CC acted as neurohaemal organ, the NSM has been reported in the aorta of almost all other heteropterans studied so far (Johansson, 1957, 1958; Seshan and Ittycheriah, 1966; Dogra, 1967*a*, *b*, *c*, 1969; Awasthi, 1972, 1973*a*, *b*; Srivastava, 1970; Furtado, 1971; Tiwari and Srivastava, 1975; Tiwari *et al.*, 1975 and Singh and Narain, 1980). In *Rhodnius prolixus*, Wigglesworth (1964) reported that CC was responsible for the storage and release of NSM whereas Faruqui (1977) in the same insect reported that a portion of CC is fused with the aorta and serves this function. He thus believed it to represent a transitional stage between the typical insect and Heteropteran condition. In *B. cruciferarum* we have observed that NSM released by the cerebral A-cells passes through the axonal fibres of NCC I and reaches the aorta which acts as a storage organ and from where it is most likely released into the general blood circulation. A sufficient amount of NSM has always been observed in the aorta.

AWASTHI (1972), TIWARI *et al.* (1975) and SINGH and NARAIN (1980) noted two corpora cardiaca with their posterior ends fused with each other. In *B. cruciferarum* the two CC are quite separate, as reported by TIWARI and SRIVASTAVA (1975) in *D. koenigii*. These workers have shown green and purple staining materials in the anterior and posterior parts of the CC, which they believed to be the intrinsic secretions of the gland. We also find similar result in *B. cruciferarum*. As the NCC I, which transports the cerebral NSM, completely bypasses the CC, NSM is not stored in the latter and aorta wall functions as NHO in this insect.

The corpus allatum is a single ovoid body, its histology is similar to that of other Heteroptera. Regarding the presence of NSM in the corpora allata, our observations are at variance with those of NAYAR (1956), SESHAN and ITTYCHERIAH (1966), AWASTHI (1972) and SRIVASTAVA *et al.* (1974). However, they are similar to those of DOGRA (1967*b*), TIWARI and SRIVASTAVA (1975) and SINGH and NARAIN (1980).

RÉSUMÉ

Des cellules neurosécrétrices internes de type 5A sont présentes dans chaque hémisphère. Les cellules B internes et externes sont absentes. Le ganglion sous-œsophagien possède deux cellules A qui ressemblent aux cellules cérébrales, mais sont de taille plus petite. Les amas ganglionnaires prothoracique et mésothoraciques fusionnés sont dépourvus de cellules neurosécrétrices. Les voies neurosécrétoires internes sont assurées par les axones descendants des cellules neurosécrétrices cérébrales. Les faisceaux axoniques des deux côtés se croisent pour constituer une paire de nerfs du corps cardiaque I. Ces derniers descendent le long des corps cardiaques et s'unissent à la paroi latérale de l'aorte dorsale. Des granules de neurosécrétion colorés par la paraldéhyde-fuchsine s'observent dans l'aorte dorsale et à aucun stade on ne les trouve dans les corps cardiaques. Une paire de nerfs du corps cardiaque II relie les corps cardiaques au cerveau. Le *corpus allatum* est simple et occupe une position postéro-médiane.

SUMMARY

5 A-type medial neurosecretory cells are present in each brain hemisphere. The lateral and median B-cells are absent. The suboesophageal ganglion has two A-cells which resemble cerebral cells but are smaller in size. The prothoracic and fused mesothoracic ganglionic mass lack NSC. The medial neurosecretory pathways are made by the descending axons of the cerebral NSC. The axonal groups of two sides cross each other to form a pair of nervi corporis cardiaci I (NCC I). The NCC I descend down, bypass corpora cardiaca (CC) and join with the lateral wall of the dorsal aorta. PF-stained neurosecretory granules are observed in the dorsal aorta which are not found at any stage in CC. A pair of NCC II connect the CC with the brain. The corpus allatum is single and posteromedially placed.

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MORPHOLOGY AND SECRETORY ACTIVITIES OF THE BRAIN AND VENTRAL NERVE CORD NEUROSECRETORY CELLS DURING THE POST-EMBRYONIC DEVELOPMENT OF POEKILOCERUS PICTUS, *FABR. (ACRIDOIDEA : PYRGOMORPHIDAE)*

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(Reçu le 23 mai 1980)

ABSTRACT. — *Distribution, size and secretory activities of neurosecretory cells (NSC) of the brain and ventral nerve cord and neuroendocrine activities of* Poekilocerus pictus *have been described in five nymphal instars, before, during and after mating males and females, and females after egg laying. 200-300 A-cells in the brain and 1 A-cells in the subesophageal ganglion have been found in the 5th instar. All the thoracic and abdominal ganglia have B, C and D-cells. The number and size of various cells have been given. Three phases (synthesis, coalescence and release) of neurosecretory cells have been observed in the Paraldehyde fuchsin-positive (PF-positive) cells of the brain.*

An increase in the number and size of A, B, C and D-cells has been noted from 2nd instar onwards. Each nymphal instar shows 4 stages of secretory cycles. The secretory cycles of adult insects differ from nymphal instars.

Key words : Neurosecretory cells, Corpora cardiaca, Corpora allata, Nervi corporis cardiaci, *Poekilocerus pictus.*

INTRODUCTION

Studies on the NSC of the brain and nerve cord have attracted attention of various workers in last two decades. Workers like