JHT
J.Het.Turk.
Journal of the Heteroptera of Turkey
ISSN 2687 - 3249 (online edition)
May, 2024
Volume 6, Issue 1

Research Article

The morphological and histological features of gastric caecum and pylorus of brown marmorated stink bug, *Halyomorpha halys* (Stål, 1855) (Hemiptera, Heteroptera, Pentatomidae)

Sıla Aydın[1], Irmak Polat[2*], Suat Kıyak[1], Neslihan Bal[1], Damla Amutkan Mutlu[1], Zekiye Suludere[1]

[1]Gazi University, Faculty of Science, Department of Biology, Ankara Türkiye

E-mail: sila.aydin@gazi.edu.tr ORCID ID: 0000-0003-4233-2954

E-mail: skiyak@gazi.edu.tr ORCID ID: 0000-0001-8167-8283

E-mail: neslihansilkin@gmail.com ORCID ID: 0000-0002-8122-7914

E-mail: damlamutkan@gazi.edu.tr ORCID ID: 0000-0002-4780-8520

E-mail: zekiyes@gazi.edu.tr ORCID ID: 0000-0002-1207-5814

[2]Çankırı Karatekin University, Faculty of Science, Department of Biology, Çankırı Türkiye

E-mail: irmakpolat@karatekin.edu.tr ORCID ID: 0000-0001-7230-4589

*Corresponding author e-mail: irmakpolat@karatekin.edu.tr

ABSTRACT: The gastric caecum and the pylorus of *Halyomorpha halys* (Stål, 1855) (Hemiptera, Pentatomidae) was examined morphologically and histologically with stereo-microscopic, light microscopic, and scanning electron microscopic (SEM) techiques in this study. *H. halys* is a polyphagous species that feeds mainly on plants of the Rosaceae and Fabaceae families and agricultural areas and can cause massive damages on them. Three

To cite this article: Aydın, S., Polat, I., Kıyak, S., Bal, N., Amutkan Mutlu, D., Suludere, Z., 2024, The morphological and histological features of gastric caecum and pylorus of brown marmorated stink bug, *Halyomorpha halys* (Stål, 1855) (Hemiptera, Heteroptera, Pentatomidae), *J.Het.Turk.*, 6(1): 54-65
DOI:10.5281/zenodo.11374332
To link to this article: https://www.j-ht.org/wp-content/uploads/2024/05/V61-A8.pdf
Received: Apr 25, 2024; **Revised:** May 28,2024; **Accepted:** May 29, 2024; **Published online:** May 31, 2024

distinct areas comprise *H. halys*'s digestive tract. The pylorus is the first section of the hindgut, and the gastric caecum of *H. halys* is seen at the posterior end of the second region known as the midgut. In comparison to other insect species in the order Hemiptera and other insect groups, it can be easily stated that their structure is generally close to many species belonging to this order.

KEYWORDS: Alimentary canal, bacteria, digestive canal, hindgut, midgut, *Halyomorpha halys*

INTRODUCTION

In recent years, the fast pace of globalization has led to a significant escalation in invasive species outbreaks affecting native biodiversity around the globe. It is no doubt that with the increase in international trade, there are many more exotic introductions ultimately lead to the establishment of foreign species. This situation may have developed accidental and intentional, but ultimately it was a problem that could lead to great economic losses. In fact, biological invasions are now second only to habitat destruction as the main factor contributing to the current decline in biodiversity (Keane and Crawley, 2002; Liu et al., 2011; Zhu et al., 2012).

Halyomorpha halys Stål (Hemiptera: Pentatomidae) (syn. *H. mista*) is one such invasive species and it is also referred to as the brown marmorated stink bug (BMSB) which is strong flier in many references. Although it is known that BMSB prefers to feed mainly on plants of the Rosaceae and Fabaceae families, it is a very polyphagous species that consumes around 300 different kinds of plants (Hoffman 1931; Lee et al. 2013; Bariselli et al., 2016; Bergmann et al. 2016; Horwood et al., 2019). *H. halys* is a fruit-piercing stink bug, causing wilting and reduced yield. This massive damage can be observed on many plants such as vegetables, orchard crops, ornamentals, grapes, nursery crops, row crops, and other small fruits. The damage caused by this insect has major economic consequences, as products with reduced yields and damaged products cannot be accepted by the markets. Adult BMSB, which are unable to reproduce, also cause secondary damage, such as the damage they cause to buildings by over-wintering inside them and the foul odours they emit when disturbed. For all these reasons it poses a major biosecurity risk (Watanabe et al. 1978, 1994; Nielsen et al. 2008a; Toyama et al., 2011; Zhu et al., 2012; Rice et al. 2014; Kriticos et al., 2017; Horwood et al., 2019).

Although *H. halys* originates from north-eastern Asia, it has also been detected in America, Europe, and Oceania, so much so that *H. halys* has been recorded in many continents and countries around the world (Horwood et al., 2019). *H. halys* is originated from China, the North and South Korea, Japan, and Taiwan in Asia. *H. halys* has invaded large areas of North America such as the USA and Canada (Bariselli et al., 2016) and Sydney (Australia) and New Zeland in Oceania. In Europe, Spain, Austria, Germany, Hungary, Bulgaria, Switzerland, France, Italy, Liechtenstein, Greece, Serbia, Romania, and Turkey are the countries where this species has been reported. Abkhazia, Georgia and Russia are other regions where this invasive species has been seen recently (Hoffman 1931; Hoebeke and Carter 2003; Rabitsch, 2008; Nielsen et al., 2008a, 2008b; Wermelinger et al. 2008; Aldrich et al., 2009; Arnold 2009; Jones and Lambin, 2009; Nielsen and Hamilton, 2009a, 2009b; Harris, 2010; Wyniger and Kment, 2010; Heckmann 2012; Zhu et al., 2012; Callot and Brua 2013; Milonas and Partsinevelos 2014; Vétek et al. 2014; Cesari et al. 2015; Macavei et al. 2015; Šeat 2015; Bariselli et al., 2016; Dioli et al. 2016; Gapon 2016; Mityushev 2016; Simov 2016; Kriticos et al., 2017).

This study's primary goal is to identify the histological and morphological structure of gastric caecum and pylorus of the alimentary canal of the widespread species, *H. halys,* that causes so much

J.Het.Turk., 6(1), May 2024 (eISSN 2687-3249)

damage. For this purpose, scanning electron microscopy and light microscopy were used to examine the structure of these organs.

MATERIALS AND METHODS

Light microscopy (LM) methods

Adult male and female specimens of *H. halys* were taken in Ankara. For light microscope studies, the gastric caecum and pylorus of ten individuals from each sexes were dissected Dissections were done with stereomicroscope (Leica EZ4D). The tissues were fixed in formaldehyde (24 h) and underwent a series of ethanol dehydration (70%, 80%, 90% and 100%) and paraffin was used to block the tissues. The 6-7 µ thick sections were cut by using a Thermo Scientific Finesse 325 Microtome and were stained with Hemotoxylin-Eosin routine staining protocol. The slides were examined (Leica DM500 light microscope) and images were taken in Çankırı Karatekin University, Faculty of Science, Zoology Laboratory.

SEM methods

For SEM studies, gastric caecum and pylorus of alimentary canals of *H. halys* were fixed in glutaraldehyde (5%, pH 7.2, with PB), underwent a (ascending) series of ethanol dehydration, and were dried (with Polaron CPD 7501). Subsequently, the samples were loaded onto SEM stubs, which were then coated with Au (with Polaron SC 502). Next, at the Prof. Dr. Zekiye Suludere Electron Microscope Center at Gazi University, the stubs were analyzed (with JEOL JSM 6060 LV SEM, 10-15 kV) and pictures were acquired.

RESULTS

Gross morphology of the alimentary canal

The foregut, midgut, and hindgut make up *H. halys*'s alimentary canal (Figure 1). When the midgut is longer than the other two portions of the alimentary canal, the foregut and hindgut are relatively short. The anterior side of the foregut is linked to the salivary glands. The anterior midgut (M1), median midgut (M2), posterior midgut (M3), and gastric caecum (M4) are the four separate regions that make up the midgut. At the pylorus, four Malpighian tubules are exposed to the alimentary canal. The pylorus and rectum are the two sections of the hindgut (Figures 2 and 3).

Gastric Caecum

H. halys individuals have four rows of gastric caecum in their digestive system. Each row of gastric caecum is gnarled structure arranged transversal axis and encircle a tube (Figure 4). The caecum is connected to the hindgut's pylorus area. (Figure 5). In the images from the cross section, there are four gastric caeca and a pylorus in the middle of them. The light microscope images show that each part of gastric caecum looks like flat sacs and has a thin wall with a single layered epithelium (Figure 6). Each gastric caecum is fulfilled with numerous micro-organisms and mostly bacteria in the cells and lumen (Figures 7 and 8). It has been observed that the gastric caecum is associated with tracheas on its outer side (Figure 4).

Pylorus

The pylorus is the first region of the hind-gut. It is associated with four Malpighian tubules in *H. halys* individuals. It can be said that the Malpighian tubules are connected to the alimentary canal at this point of the hindgut (Figure 3).
The secretion produced by the epithelial cells of the Malpighian tubules meets with food residue in the lumen of the alimentary canal in pylorus. The cross sections of the pylorus show that the monolayered cylindrical epithelium and large lumen (Figure 9).

DISCUSSION

In insects, the caecum is where the majority of the digestive enzymes are

J.Het.Turk., 6(1), May 2024 (eISSN 2687-3249)

created. The digestion process in insects is carried out by the function of gastric caecum enzymes and, in addition, with the help of symbiont bacteria living in the caecum. In fact, many studies have shown that the gastric caecum lumen is almost completely covered with bacteria (Glasgow, 1914; Chapman, 1998; Ferreira et al., 1999). The formation of caecum in many insects is very different from one order to another in terms of morphology, number, size, and position, while the histological structures are very similar. The structures of gastric caeca differ greatly depending on the degree of development of the families in which they are found. The digestive tract of some species does not have a gastric caecum. *Graptostcthus scrvus* (Hemiptera, Lygaeidae), *Sphex flavipennis* Fabricius, 1793 (Hymenoptera, Sphecidae), and *Lygaeus trivittatus* (Hemiptera, Lygaeidae) are some of such species without gastric caecum (Glasgow, 1914; Kurup, 1964; Demir & Suiçmez, 2011; Gangurde et al., 2019). In insects belonging to the order Heteroptera, the midgut is generally divided into four regions. Gastric caecum is generally seen as the fourth region. As in *H. halys* examined in this study, the midgut in *Halys dentatus* (Hemiptera, Pentatomidae) has 4 regions and the last region is called gastric caecum (Gangurde et al., 2019; Şimşek et al., 2020).

Numerous microorganisms, particularly bacteria, are present in the lumen of the gastric caecum of *H. halys* like many other species that were examined by various researchers before such as *Leptocorisa chinensis* Dallas, 1852 (Hemiptera, Alydidae), *Nezara viridula* (L.) (Heteroptera, Pentatomidae), *Riptortus clavatus* (Thunberg, 1783) (Hemiptera, Alydidae) *Eurydema rugosa* Motschulsky (Heteroptera: Pentatomidae) and *Eurydema dominulus* (Scopoli) (Heteroptera: Pentatomidae). These bacteria in the gastric caecum live symbiotically with the host organism, aiding in the digestion of nutrients or producing antibiotic barriers against pathogens (West, 1980; Kikuchi et al., 2005, 2012; Hirose et al., 2006; Tada et al., 2011; Zucchi et al., 2012).

The hindgut, which is the last part of the digestive tract in insects, shows variations in different insect groups, as in other parts. The hindgut is divided into 3 parts in some insect species. These 3 parts, which are called ileum, colon and rectum in some, can be seen as ileum, rectal caecum and rectum in some species such as *Abedus ovatus* (Stål) (Hemiptera, Belostomatidae). In some species, such as *Ceroplastes japonicus* (Green) (Hemiptera: Coccoidea), the hindgut is divided into two: pylorus and rectum as in *H. halys*. In *Lepyronia coleopterata* (L.) the 2 hindgut layers are called ileum and rectum (Goverdhan et al., 1981; Xie et al., 2011; Zhong et al., 2013).

When *H. halys*'s pylorus and gastric caecum features were contrasted with those of other species belonging to the Hemiptera order, it was observed that it was quite similar to other species in terms of number, location and structure.

EFERENCES

Aldrich J. R., Khrimian, A., Chen, X., Camp, M. J., 2009, Semiochemically based monitoring of the invasion of the brown marmorated stink bug and unexpected attraction of the native green stink bug (Heteroptera: Pentatomidae) in Maryland. *Florida Entomologist,* 92: 483-491.

Arnold, K., 2009, *Halyomorpha halys* (Stål, 1855), Eine für die europäische Fauna neu nachgewiesene Wanzenart (Insecta: Heteroptera: Pentatomidae: Cappaeini). *Mitteilungen des Thüringer Entomologenverbandes*, 16.

Bariselli, M., Bugiani, R., Maistrello, L., 2016, Distribution and damage caused by *Halyomorpha halys* in Italy. *Eppo Bulletin*, 46(2): 332-334.

Bergmann, E. J., Venugopal, P. D., Martinson, H. M., Raupp, M. J., Shrewsbury, P. M., 2016, Host plant use by the invasive *Halyomorpha halys* (Stål)

J.Het.Turk., 6(1), May 2024 (eISSN 2687-3249)

on woody ornamental trees and shrubs. *PLoS ONE*, 11: e0149975.

Callot, H., Brua, C., 2013, *Halyomorpha halys* (Stål, 1855), la Punaise diabolique, nouvelle espèce pour la faune de France (Heteroptera Pentatomidae). *L'Entomologiste*, 69: 69-71.

Cesari, M., Maistrello, L., Ganzerli, F., Dioli, P., Rebecchi, L., Guidetti, R., 2015, A pest alien invasion in progress: potential pathways of origin of the brown marmorated stink bug *Halyomorpha halys* populations in Italy. *Journal of Pest Science*, 88: 1-7.

Chapman, R., 1998, Alimentary canal, digestion and absorption, Cambridge University Press, UK.

Demir, F., Suicmez, M., 2011, Investigation of digestive tract of *Sphex flavipennis* Fabricius, 1793 (Hymenoptera: Sphecidae): Morphology and ultrastructure. G*azi University Journal of Science,* 24(3): 397-405.

Dioli, P., Leo, P., Maistrello, L., 2016, Prime segnalazioni in Spagna e in Sardegna della specie aliena *Halyomorpha halys* (Stål, 1855) e note sulla sua distribuzione in Europa (Hemiptera, Pentatomidae). *Revista Gaditana de Entomología,* 7: 539-548.

Ferreira, C., Marana, S. R., Silva, C., Terra, W. R., 1999, Properties of digestive glycosidases and peptidases and the permeability of the peritrophic membranes of *Abracris flavolineata* (Orthoptera: Acrididae), *Comparative Biochemistry and Physiology Part B,* 123: 241250.

Gangurde, J. H., Gurule, S. A., Tidame, S. K., 2019, Anatomy and histopathology of alimentary canal of *Halys dentatus* (Hemiptera: Pentatomidae) treated with dichlorovos, *Indian Journal of Applied Research*, 9(10): 61-66.

Gapon, D. A., 2016, First records of the brown marmorated stink bug *Halyomorpha halys* (Stål, 1855) (Heteroptera, Pentatomidae) in Russia, Abkhazia, and Georgia. *Entomological Review,* 96: 1086-1088.

Glasgow, H., 1914, The gastric caeca and the caecal bacteria of the Heteroptera, *The Biological Bulletin,* 26(3):101-170.

Goverdhan, T. L., Shyamasundari, K., Rao, K. H., 1981, Histology and histochemistry of the alimentary canal of *Abedus ovatus* (Stal) (Heteroptera: Belostomatidae). *Proceedings: Animal Sciences*, 90(2): 237-251.

Harris, A. C., 2010, *Halyomorpha halys* (Hemiptera: Pentatomidae) and *Protaetia brevitarsis* (Coleoptera: Scarabaeidae: Cetoniinae) intercepted in Dunedin. *The Weta,* 40: 42-44.

Heckmann, R., 2012, Erster Nachweis von *Halyomorpha halys* (STÅL, 1855) (Heteroptera: Pentatomidae) für Deutschland. *Heteropteron,* 36: 17-18.

Hirose, E., Panizzi, A. R., De Souza, J. T., Cattelan, A. J., Aldrich, J. R., 2006, Bacteria in the gut of southern green stink bug (Heteroptera: Pentatomidae). *Annals of the Entomological Society of America,* 99(1): 91-95.

Hoebeke, E. R., Carter, M. E., 2003, *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae): A polyphagous plant pest from Asia newly detected in North America. *Proceedings of the Entomological Society of Washington,* 105: 225-237.

Hoffman, W. E., 1931, A pentatomid pest of growing beans in South China. *Peking Natural History Bulletin,* 5: 25-26

Horwood, M., Milnes, J. M., Cooper, W. R., 2019, Brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Pentatomidae), detections in Western Sydney, New South Wales, Australia. *Austral Entomology*, 58(4): 857-865.

Jones, J. R., Lambin, P. L., 2009, New county and state records for Tennessee of an exotic pest, *Halyomorpha halys* (Hemiptera: Pentatomidae), with potential economic and ecological implications. *Florida Entomologist,* 92: 177-179.

Keane, R. M., Crawley, M. J., 2002, Exotic plant invasions and the enemy release hypothesis. *Trends in Ecology and Evolution,* 17: 164-170.

Kikuchi, Y., Meng, X. Y., Fukatsu, T., 2005, Gut symbiotic bacteria of the genus Burkholderia in the broad-headed bugs *Riptortus clavatus* and *Leptocorisa chinensis* (Heteroptera: Alydidae). *Applied Environmental Microbiology*, 71(7): 4035-4043.

Kikuchi, Y., Hosokawa, T., Nikoh, N., Fukatsu, T., 2012, Gut symbiotic bacteria in the cabbage bugs *Eurydema rugosa* and *Eurydema dominulus* (Heteroptera: Pentatomidae). *Applied Entomology and Zoology*, 47: 1-8.

Kriticos, D. J., Kean, J. M., Phillips, C. B., Senay, S. D., Acosta, H., Haye, T., 2017, The potential global distribution of the brown marmorated stink bug, *Halyomorpha halys*, a critical threat to plant biosecurity. *Journal of Pest Science,* 90: 1033-1043.

Kurup, N. G., 1964, A study of the digestive tract of four Indian gymnocerate Hemiptera, *Annals of the Entomological Society of America*, 57(2): 200-209.

Lee, D. H., Short, B. D., Joseph, S. V., Bergh, J. C., Leskey, T. C., 2013, Review of the biology, ecology, and management of *Halyomorpha halys* (Hemiptera: Pentatomidae) in China, Japan, and the Republic of Korea. *Environmental Entomology*, 42: 627-641.

Liu, X., Guo, Z., Ke, Z., Wang, S., Li, Y., 2011, Increasing potential risk of a global aquatic invader in Europe in contrast to other continents under uture climate change. *PloS One*, 6(3): e18429.

Macavei, L., Băețan, R., Oltean, I., Florean, T., Varga, M., Costi, E., Maistrello, L., 2015, First detection of *Halyomorpha halys*, a new invasive species with a high potential of damage on agricultural crops in Romania. *Lucrari Stiintifice Seria Agronomie*, 58: 105-108.

Milonas, P., Partsinevelos, G., 2014, First report of brown marmorated stink bug *Halyomorpha halys* Stål (Hemiptera: Pentatomidae) in Greece. *EPPO Bull,* 44: 183-186.

Mityushev, I. M., 2016, First record of marmorated bug detection in Russia. *Zashchita Karantin Rasteniĭ*, 3: 48.

Nielsen, A. L., Hamilton, G. C., 2009a, Seasonal occurrence and impact of *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae): A polyphagous plant pest from Asia newly detected in north America. *Journal of Economic Entomology*, 102: 1133-1140.

Nielsen, A. L., Hamilton, G. C., 2009b, Life history of the invasive species *Halyomorpha halys* (Hemiptera: Pentatomidae) in Northeastern United States. *Annals of the Entomological Society of America,* 102: 608-616.

Nielsen, A. L., Shearer, P. W., Hamilton, G. C., 2008a, Toxicity of insecticides to *Halyomorpha halys* (Hemiptera: Pentatomidae) using glass-vial bioassays. *Journal of Economic Entomology*, 101: 1439-1442.

Nielsen, A. L., Hamilton, G. C., Matadha, D., 2008b, Developmental rate estimation and life table analysis for *Halyomorpha halys* (Hemiptera: Pentatomidae). *Environmental Entomology,* 37: 348-355.

Rabitsch, W., 2008, Alien true bugs of Europe (Insecta: Hemiptera: Heteroptera). *Zootaxa*, 1827: 1-44.

Rice, K. B., Bergh, C. J., Bergmann, E. J., Biddinger, D. J., Dieckhoff, C., Dively, G., Fraser, H., Gariepy, T., Hamilton, G., Haye, T., Herbert, A., Hoelmer, K., Hooks, C. R., Jones, A., Krawczyk, G., Kuhar, T., Martinson, H., Mitchell, W., Nielsen, A. L., Pfeiffer, D. G., Raupp,

J.Het.Turk., 6(1), May 2024 (eISSN 2687-3249)

M. J., Rodriguez-Saona, C., Shearer, P., Shrewsbury, P., Venugopal, D. P., Whalen, J., Wiman, N. G., Leskey, T. C., Tooker, J. F., 2014, Biology, ecology, and management of brown marmorated stink bug (Hemiptera: Pentatomidae). *Journal of Integrated Pest Management*, 5(3): A1-A13.

Šeat, J., 2015, *Halyomorpha halys* (Stål, 1855) (Heteroptera: Pentatomidae) a new invasive species in Serbia. *Acta Entomologica Serbica*, 20: 167-171.

Simov, N., 2016, The invasive brown marmorated stink bug *Halyomorpha halys* (Stål 1855 (Heteroptera: Pentatomidae) already in Bulgaria. *Ecologica Montenegrina,* 9: 51-53.

Şimşek, O., Amutkan, Mutlu, D., Polat, I., Suludere, Z., 2020, Notes on the gastric ceacum of *Centrocoris variegatus* Kolenati, 1845 (Heteroptera, Coreidae): Light and scanning electron microscopic study. *Journal of the Heteroptera of Turkey*, 2(1): 53-61.

Tada, A., Kikuchi, Y., Hosokawa, T., Musolin, D. L., Fujisaki, K., Fukatsu, T., 2011, Obligate association with gut bacterial symbiont in Japanese populations of the southern green stinkbug *Nezara viridula* (Heteroptera: Pentatomidae). *Applied Entomology and Zoology,* 46: 483-488.

Toyama, M., Ihara, F., Yaginuma, K., 2011, Photo-response of the brown marmorated stink bug, *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae), and its role in the hiding behavior. *Applied Entomology and Zoology*, 46: 37-40.

Vétek, G., Papp, V., Haltrich, A., Rédei, D., 2014, First record of the brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Heteroptera: Pentatomidae), in Hungary, with description of the genitalia of both sexes. *Zootaxa,* 3780:194-200.

Watanabe, M., Arakawa, R., Shinagawa, Y., Okazawa, T., 1994, Anti-invading methods against the brown marmorated stink bug, *Halyomorpha mista*, in houses. *Japanese Journal of Sanitary Zoology*, 45: 311-317.

Wermelinger, B., Wyniger, D., Forster, B., 2008, First records of an invasive bug in Europe: *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae), a new pest on woody ornamentals and fruit trees? *Mitteilungen der Schweizerischen Entomologischen Gesellschaft,* 81: 1-8.

West, R. P., 1980, Endosymbiosis in the caecum of the southern green stink bug, *Nezara viridula* (L.). *Louisiana State University and Agricultural & Mechanical College*.

Wyniger, D., Kment, P., 2010, Key for the separation of *Halyomorpha halys* (Stål) from similar-appearing pentatomids (Insecta: Heteroptera: Pentatomidae) occurring in Central Europe, with new Swiss records. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft*, 83: 261-270.

Xie, Y., Liu, W., Zhang, Y., Xiong, Q., Xue, J., Zhang, X., 2011, Morphological and ultrastructural characterization of the alimentary canal in Japanese wax scale (Ceroplastes japonicus Green). *Micron*, 42(8): 898-904.

Zhong, H., Zhang, Y., Wei, C., 2013, Anatomy and fine structure of the alimentary canal of the spittlebug *Lepyronia coleopterata* (L.) (Hemiptera: Cercopoidea). *Arthropod Structure and Development,* 42(6): 521-530.

Zhu, G., Bu, W., Gao, Y., Liu, G., 2012, Potential geographic distribution of brown marmorated stink bug invasion (*Halyomorpha halys*). *PLoS ONE,* 7(2): e31246.

Zucchi, T. D., Prado, S. S., Cônsoli, F. L., 2012, The gastric caeca of pentatomids as a house for actinomycetes. *BMC Microbiology*, 12: 1-7.

J.Het.Turk., 6(1), May 2024 (eISSN 2687-3249)

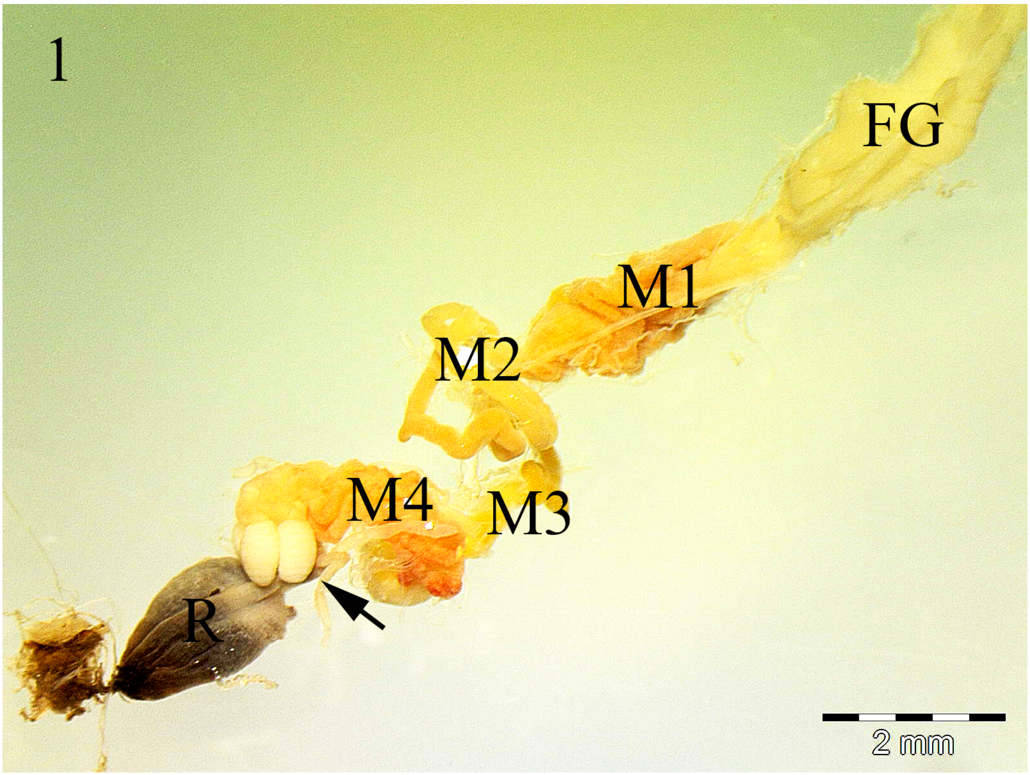

Figure 1. Stereomicroscope image of the alimentary canal in *H. halys*. FG: foregut, M1: anterior midgut, M2: median midgut, M3: posterior midgut, M4: gastric caecum, arrow: Malpighian tubule, R: rectum.

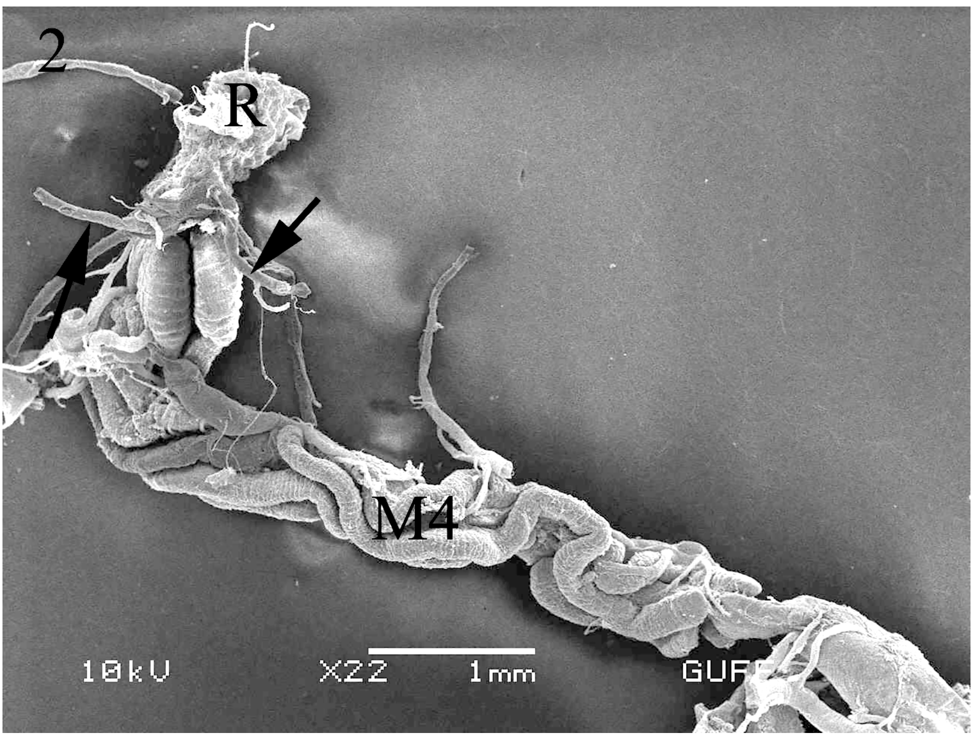

Figure 2. SEM image of the outer surface of gastric caecum (M4), rectum (R), and Malpighian tubules (arrows).

J.Het.Turk., 6(1), May 2024 (eISSN 2687-3249)

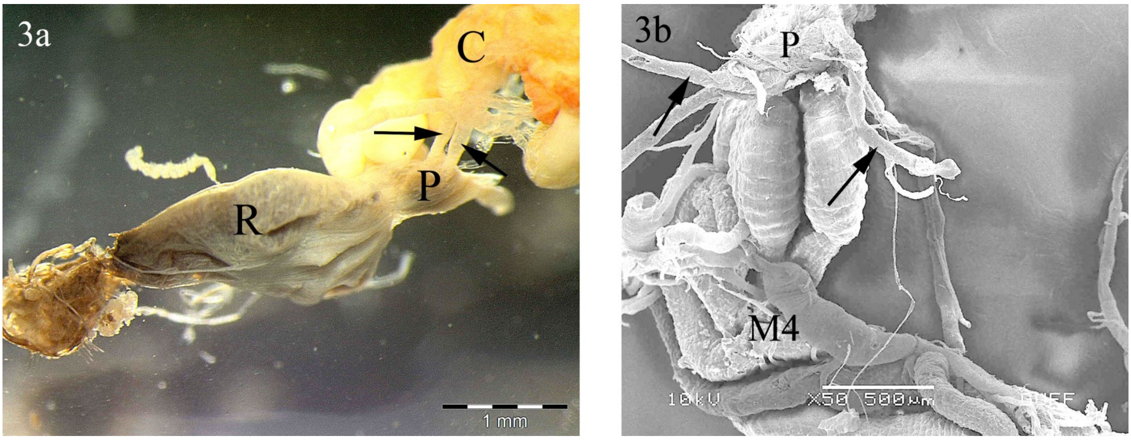

Figure 3. The connection junction of gastric caecum (M4), pylorus (P) and Malpighian tubules (arrows). a. Stereomicroscope image, b. SEM image (R: rectum).

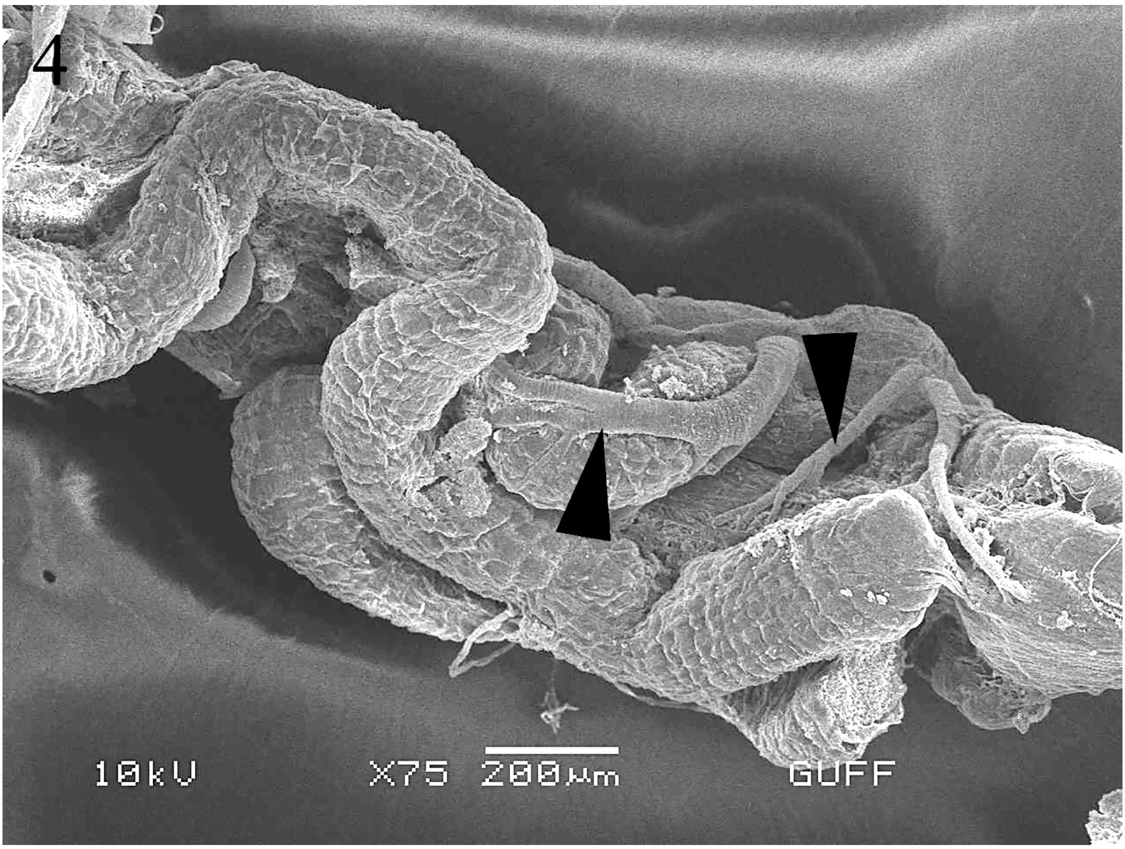

Figure 4. SEM image of the outer surface of gastric caecum associated with trachea (arrowheads).

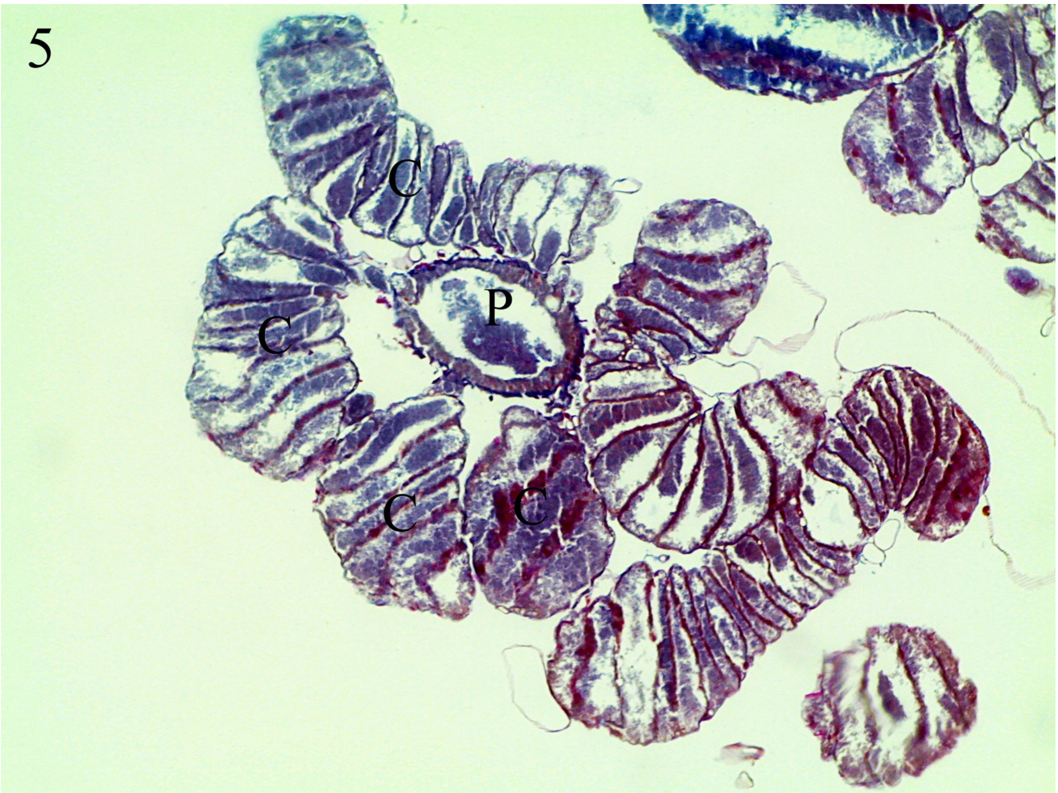

Figure 5. Light microscopic image of the cross section of gastric caecum (C) and pylorus (P). (Magnification: X100).

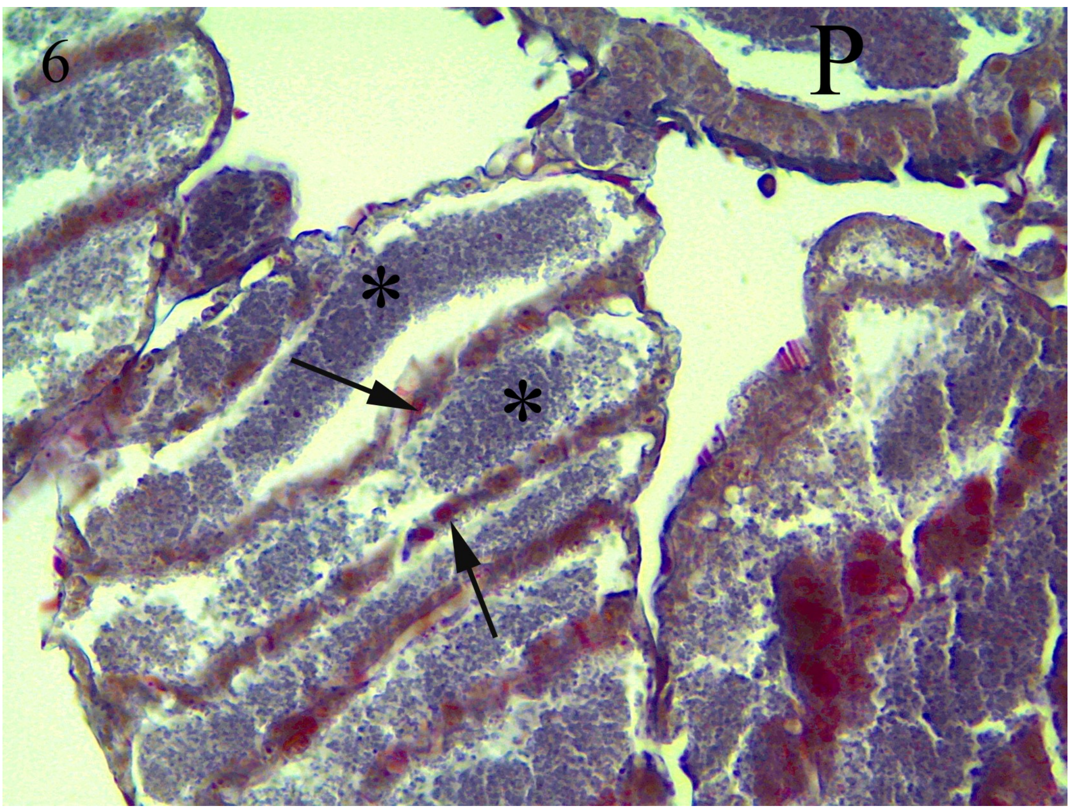

Figure 6. Light microscopic image of the cross section of gastric caecum. Arrows: nucleus of epithelial cells, asterisks: bacteria in the lumen, P: pylorus. (Magnification: X4100).

J.Het.Turk., 6(1), May 2024 (eISSN 2687-3249)

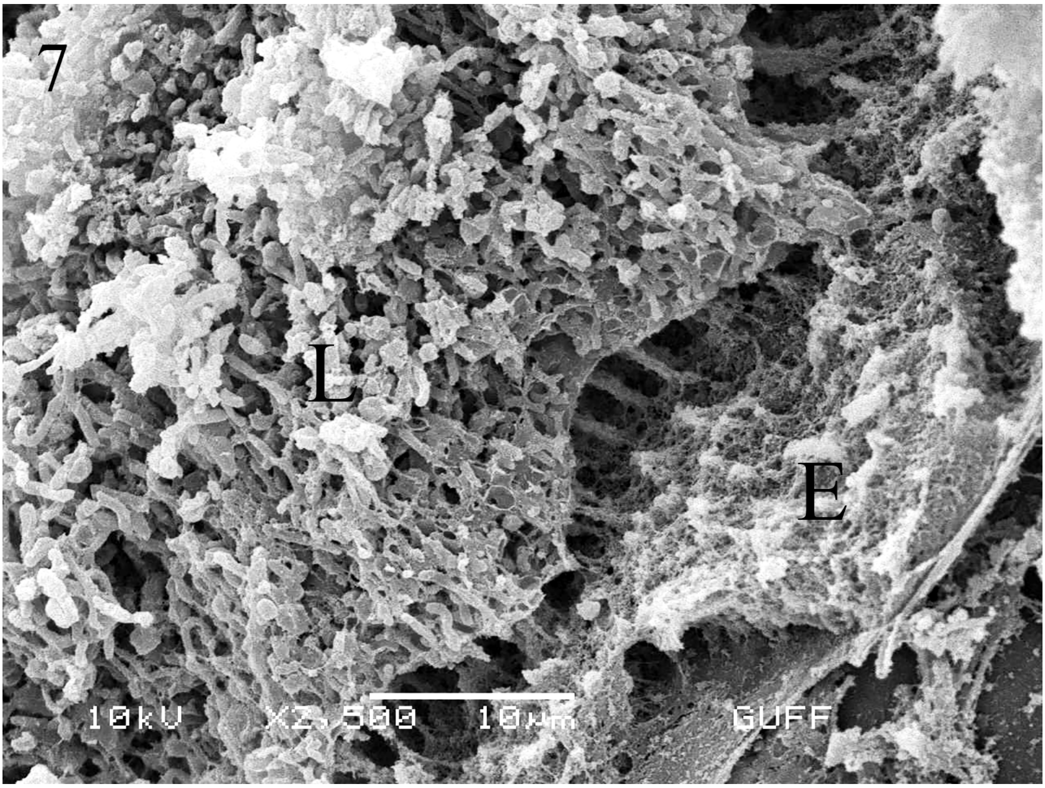

Figure 7. SEM image of the epithelial layer (E) of the gastric caecum and lumen (L) full of bacteria.

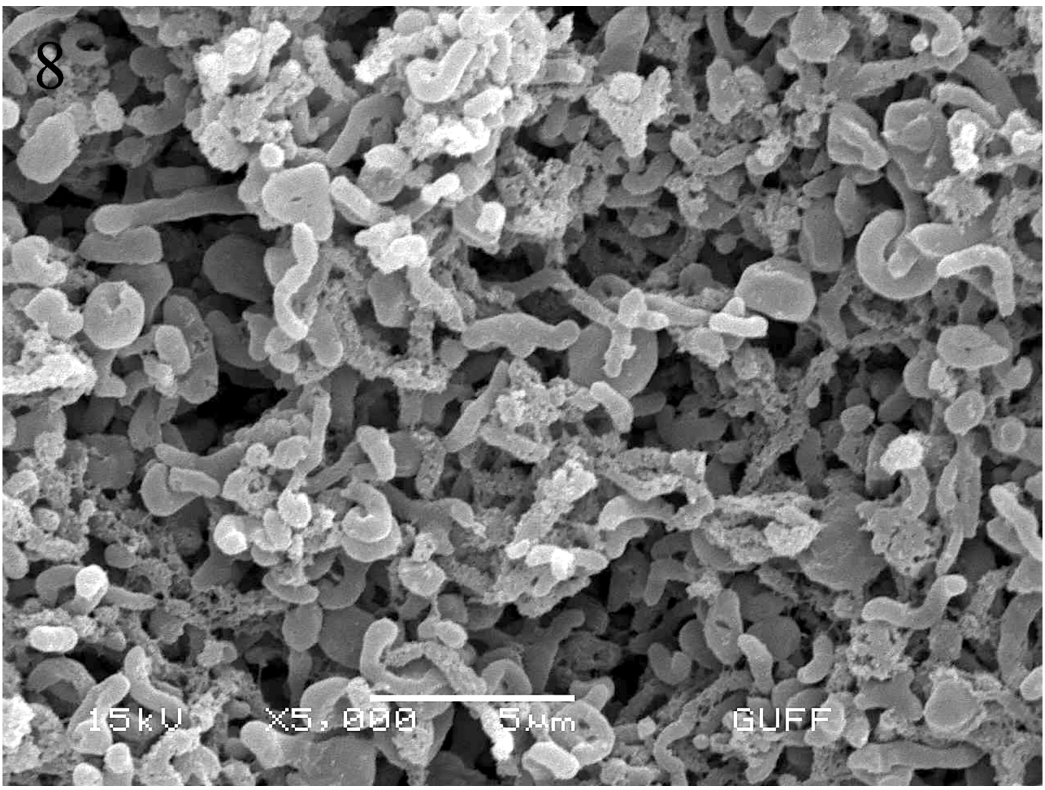

Figure 8. SEM image of the bacteria in the lumen of the gastric caecum.

J.Het.Turk., 6(1), May 2024 (eISSN 2687-3249)

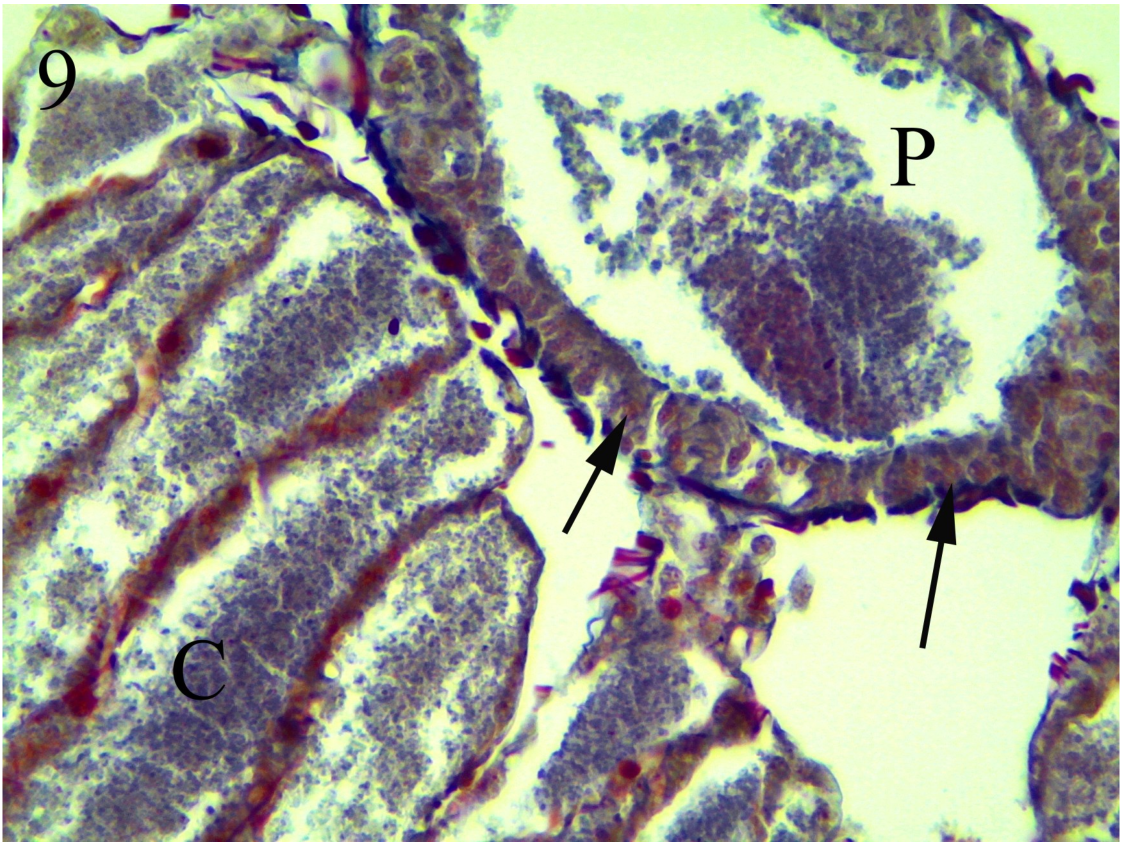

Figure 9. The light microscopic image of the cross section of the pylorus (P). Arrows: nucleus of the epithelial cells, C: gastric caecum. (Magnification: X4100).