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*Editorial*

# Rodents in Crop Production Agricultural Systems—Special Issue

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## 1. Introduction

Rodents are among the major pests that have accompanied human society and agriculture since ancient times. As ecological opportunists, they are frequently associated with fields, orchards, farms, livestock stables, grain stores, food industry facilities, and many other places in the agricultural and anthropogenic environment [1,2]. Rodent harmfulness lies not only in the quantitative damage and crop loss they cause [3,4], but also in the risk of contamination of food stores by feces and urine [5–7], vectorship of mycotoxigenic fungi on stored crops and commodities [8], and transmitting diseases to humans or livestock [2,9]. In addition, unattended rodenticide baits may become sources of infestation for storage arthropods, since many arthropod pests may feed and develop on rodent baits [10]. Some harmful species of synanthropic rodents are classified as invasive organisms with economic and environmental impacts on native fauna and flora [11–13]. It is thus obvious that rodents have a high societal significance with implications for many human activities in both the human-made and natural environment. Effective control of agriculturally important rodents is essential not only from an economic point of view, but also from the point of view of ensuring food security and safety as well as national public health in each country. However, the numbers of scientists and thus publications dealing with rodents are still small in relation to the numbers of scientists and publications concerning insect pests [14]. Given this shortage of research and the agricultural and societal importance of rodents, a call for a Special of Agronomy was therefore prepared, with the title "Rodents in Crop Production Agricultural Systems" (https://www.mdpi.com/journal/agronomy/special_issues/rodents_crop) (accessed on 26 October 2022). From the current areas of interest related to integrated rodent control, the following range of topics was chosen: rodent monitoring, control, rodenticides, repellents, attractants, biological rodent control, secondary intoxications, damage caused by rodents in fields and commodity stores, rodent population dynamics, rodent health risks to humans and animals, case studies from the field, and policy positions. This appeal has had a positive response in the rodentology community in the form of the submission of a number of high quality articles. The result was a published set of eight thematic articles [3,4,15–20]. These articles included 23 authors from five geographical areas that include Australia, the Czech Republic, Serbia, Taiwan, and the USA (California and Colorado). The prepared articles largely covered six key species of pest rodents, including *Microtus arvalis* [4,15,18], *Mus musculus* [3,17], *Rattus rattus* [19], *Arvicola amphibius*, *Microtus agrestis* and *Clethrionomys glareolus* [4]. Regarding these rodent pests, the articles thematically cover a number of important topics in the field of rodent control and risk management. The content of the accepted and published works is briefly described in the following two sections.

## 2. Evaluation of Rodent Impacts on Crops and Orchards

The body of published work in this Special Issue on the negative impacts of rodents in agriculture includes two review publications [15,20], and two regular publications [3,4]. Witmer [20] overviewed various types of damages caused by rodents and their extent on a worldwide scale. He documented that damage levels in crops can vary from insignificant to very significant (>30%) or to almost complete crop loss. As an example of the severe



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levels of rodent damage that can occur, he reported that in Asia alone, the amount of grain consumed by rodents would provide enough food to feed 200 million people for a year. In addition, Witmer [20] provided an extensive account of the main rodent genera that cause significant damage to human resources and property in various countries and continents. The recent extraordinary increase in the population of *M. arvalis* in Middle Europe was the motivation for the literature review provided by Aulicky et al. [15]. The aim of this paper was to map the historical outbreaks and crop damage caused by the common vole in Czech Republic territory. The published records of vole population outbreaks and heavy crop damage have been documented in the Czech literature since the turn of the 20th century, even in crops planted in highly fragmented and diversified agricultural landscapes. This overview is thematically followed by the publication of Suchomel et al. [4]. They reported an unusual damage of apple tree orchards by rodents in two localities in the Czech Republic. In 2019, 24% of trees in the Czech orchard were gnawed by the common vole population. Recent work on rodent damage is also related to the exceptionally widespread increase in pests in agricultural landscapes and farms. This is specifically related to the increase in house mouse numbers in Australia [3]. Brown and Henry [3] claimed that losses caused by mice were estimated to amount to AUD 140,000 (range = AUD 7000–461,580; equivalent to 30–40% loss of value) and included estimates of physical damage to hay/fodder bales, rodenticides, and labor costs.

## 3. Rodent Control and Monitoring

In terms of rodent control or monitoring, the published papers in this Special Issue include explorations of the use of baits and other chemical methods [15,17,18,20], the attractiveness of various types of non-toxic monitoring baits [3], and a survey-based analysis of the conditions under which different methods for rodent control are used in practice [16]. The current global policy trend is a general reduction in the number of registered chemicals for the control of pests of agricultural and epidemiological importance, whether in terms of rodenticides or insecticides or other types of pesticides and biocides [1,15,21,22]. For example, the review by Aulicky et al. [15] in this Special Issue notes that in the 1930s there were more than 100 various rodent preparations against the common vole in the Czech regions (current Czech Republic—CR). Currently, there are only six preparations with three active ingredients registered in the CR. Zinc phosphide is the only active ingredient that has been used from the 1940s to the present, whereas anticoagulants were banned for vole control in the CR in 2011 owing to the high environmental risks. Such a trend inevitably reduces the possibilities for effective rodent control and enhances the risk of increasing rodent resistance. However, despite the reduction in rodenticide active ingredients, many current rodent management practices still rely on chemical products. Best et al. [16] reported results from a survey of 126 Taiwan farmers on their knowledge, attitudes, and control practices for rodent pests of agricultural importance. One-third of the farmers stated that they currently use rodenticides. However, the results indicate environmentally friendly practices given that the use of rodenticides is mainly reactive as opposed to preventative.

Formulations involved in the current rodent pest control programs are mainly based on acute (e.g., zinc-phosphide) or chronic (e.g., anticoagulants) rodenticides. Anticoagulants show a delayed toxic physiological response in the affected rodents [23,24] and accumulate in the body of poisoned rodents. Secondary poisoning of natural scavengers or predators may follow after the consumption of the intoxicated rodent bodies. Therefore, effective and safe rodent control and monitoring is a challenge. The papers included in this Special Issue [15,16,18,20] highlight, among other things, the importance of rodenticide products and identify application procedures that are not only sufficiently effective, but also limit negative effects on non-target organisms. However, designing the appropriate bait formulation for the target rodent species is difficult in terms of balancing the type and concentration of active ingredients, and its attractiveness, palatability, and safety. Reliable and economical methods for laboratory screening/testing of baits are needed under laboratory and field conditions. This Special Issue also covers this aspect of rodent control [17,18].

Namely, Frankova et al. [17] compared the simple no-choice with the more economically demanding choice feeding tests for the laboratory evaluation of the efficacy of rodenticide anticoagulant-based preparations in wild populations of house mice. They analyzed the mice survival and bait intake of the various rodenticide commercial preparations differing in their toxic active substance (warfarin, bromadiolone, brodifacoum, difethialone) and nontoxic food lure components. They mostly found insignificant differences in the survival of mice treated with eight examined baits within the no-choice and choice feeding tests. They discussed implications of this finding for the standardization of rodent bait testing approaches. Jokic and Blazic [18] explored the efficacy of the most widely used acute rodenticide zinc phosphide and anticoagulants (bromadiolone and brodifacoum) on common voles; baits were applied at reduced doses of active ingredients and as a mixture of both active ingredients. All the baits tested, including baits based on the two active ingredients, showed satisfactory results. The authors claimed that the use of anticoagulant rodenticides with reduced contents of active ingredients may significantly reduce their exposure to non-target animals.

New works on innovative rodenticide formulations associated with gels (that are often called rodenticide "soft baits"), liquids, polymers, and encapsulated active compounds point the way towards further development to effectively manage rodent populations and mitigate the negative effects of rodenticides [25–27]. Gels and liquids can be used not only for direct rodent control but also as a suitable matrix for the formulation of repellents [28] and antifeedants or as attractants for rodent monitoring using nontoxic baits. Non-toxic soft baits are increasingly used to monitor rodent abundance in commensal settings [29] and may be an effective attractant in agricultural fields as well. For example, in this Special Issue, Brown and Henry [3] evaluated the attractiveness of a soft bait, a wax block, peanut butter, and a control (i.e., no bait applied) to roof rats when applied within tracking tunnels. They did not observe a difference in visitation to any of the tested attractants, although all attractants yielded greater visitation rates than control tunnels. They concluded that monitoring tools that provide shelter may increase the detectability of rodents.

## 4. Conclusions

Apart from the extensive pest control effort in the private sector, or by international organizations (FAO, WHO, etc.) or governments, there are still substantial damages caused by rodents to agricultural production and the food industry. The increasingly severe issue of rodent infestations—associated with a large increase in rodent populations [3,15,30,31] and ecological invasions [13]—is particularly important in the context of climactic changes [32–34]. The epidemiological risks of rodents [9,35] and their negative impacts on crops and stored agricultural commodities are particularly significant in light of conflicts and crises in food distribution due to the COVID-19 pandemic and the increasing urbanization of rural and natural landscapes [36]. We hope that this Special Issue will help to stimulate targeted research and the development of advanced procedures for managing rodent pests in the future. Due to the positive international response from a number of specialist authors on the topic of harmful rodents in agriculture, the next volume of this Special Issue has been prepared. The editors have opened a new call for papers in the Special Issue "Rodents in Crop Production Agricultural Systems—2nd Edition"—Dr. Radek Aulický, Dr. Marcela Fraňková—Guest Editors (https://www.mdpi.com/journal/agronomy/special_issues/S26Q67959N) (accessed on 3 November 2022).

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## References


1. Jacob, J.; Manson, P.; Barfknecht, R.; Fredricks, T. Common vole (*Microtus arvalis*) ecology and management: Implications for risk assessment of plant protection products. *Pest Manag. Sci.* **2014**, *70*, 869–878. [CrossRef] [PubMed]
2. Buckle, A.; Smith, R. *Rodent Pests and Their Control*, 2nd ed.; CABI International: Wallingford, UK, 2015.
3. Brown, P.R.; Henry, S. Impacts of House Mice on Sustainable Fodder Storage in Australia. *Agronomy* **2022**, *12*, 254. [CrossRef]
4. Suchomel, J.; Šipoš, J.; Ouředníčková, J.; Skalský, M.; Heroldová, M. Bark Gnawing by Rodents in Orchards during the Growing Season—Can We Detect Relation with Forest Damages? *Agronomy* **2022**, *12*, 251. [CrossRef]
5. Frankova, M.; Kaftanova, B.; Aulicky, R.; Rodl, P.; Frynta, D.; Stejskal, V. Temporal production of coloured faeces in wild roof rats (*Rattus rattus*) following consumption of fluorescent non-toxic bait and a comparison with wild *R. norvegicus* and *Mus musculus*. *J. Stored Prod. Res.* **2019**, *81*, 7–10. [CrossRef]
6. Stejskal, V.; Aulický, R. Field evidence of roof rat (*Rattus rattus*) faecal contamination of barley grain stored in silos in the Czech Republic. *J. Pest Sci.* **2014**, *87*, 117–124. [CrossRef]
7. Aulicky, R.; Stejskal, V.; Pekar, S. Risk Evaluation of Spatial Distribution of Faecal Mice Contaminants in Simulated Agricultural and Food Store. *Pak. J. Zool.* **2015**, *47*, 1037–1043.
8. Stejskal, V.; Hubert, J.; Kubatova, A.; Váňová, M. Fungi associated with rodent feces in stored grain environment in the Czech Republic. *J. Plant Dis. Prot.* **2005**, *112*, 98–102.
9. Meerburg, B.G.; Singleton, G.; Kijlstra, A. Rodent-borne diseases and their risks for public health. *Crit. Rev. Microbiol.* **2009**, *35*, 221–270. [CrossRef]
10. Vendl, T.; Frankova, M.; Aulicky, R.; Stejskal, V. First record of the development of *Sitophilus oryzae* on two rodent bait formulations and literature overview of stored product arthropods infestations in rodent baits. *J. Stored Prod. Res.* **2020**, *86*, 101557. [CrossRef]
11. Jones, H.P.; Tershy, B.R.; Zavaleta, E.S.; Croll, D.A.; Keitt, B.S.; Finkelstein, M.E.; Howald, G.R. Severity of the Effects of Invasive Rats on Seabirds: A Global Review. *Conserv. Biol.* **2008**, *22*, 16–26. [CrossRef]
12. Mackenzie, H.R.; Latham, M.C.; Anderson, D.P.; Hartley, S.; Norbury, G.L.; Latham, A.D.M. Detection parameters for managing invasive rats in urban environments. *Sci. Rep.* **2022**, *12*, 16520. [CrossRef] [PubMed]
13. Harris, H.A.L.; Kelly, D.; Innes, J.; Allen, R.B. Invasive species and thermal squeeze: Distribution of two invasive predators and drivers of ship rat (*Rattus rattus*) invasion in mid-elevation Fuscospora forest. *Biol. Invasions* **2022**, *24*, 2547–2559. [CrossRef]
14. Stejskal, V.; Honěk, A. Is species diversity of various crop “pest taxa” proportionate to efforts paid to their research? A scientometric analysis in the Czech Republic-short note. *Plant Prot. Sci.* **2015**, *51*, 191–194. [CrossRef]
15. Aulicky, R.; Tkadlec, E.; Suchomel, J.; Frankova, M.; Heroldová, M.; Stejskal, V. Management of the Common Vole in the Czech Lands: Historical and Current Perspectives. *Agronomy* **2022**, *12*, 1629. [CrossRef]
16. Best, I.N.; Shaner, P.-J.L.; Pei, K.J.-C.; Kuo, C.-C. Farmers’ Knowledge, Attitudes, and Control Practices of Rodents in an Agricultural Area of Taiwan. *Agronomy* **2022**, *12*, 1169. [CrossRef]
17. Frankova, M.; Aulicky, R.; Stejskal, V. Efficacy of Eight Anticoagulant Food Baits in House Mouse (*Mus musculus*): Comparison of Choice and No-Choice Laboratory Testing Approaches. *Agronomy* **2022**, *12*, 1828. [CrossRef]
18. Jokić, G.; Blažić, T. Control of Common Vole (*Microtus arvalis*) in Alfalfa Crops Using Reduced Content of Anticoagulants. *Agronomy* **2021**, *12*, 53. [CrossRef]
19. Wales, K.N.; Meinerz, R.; Baldwin, R.A. Assessing the Attractiveness of Three Baits for Roof Rats in California Citrus Orchards. *Agronomy* **2021**, *11*, 2417. [CrossRef]
20. Witmer, G. Rodents in Agriculture: A Broad Perspective. *Agronomy* **2022**, *12*, 1458. [CrossRef]
21. Buckle, A.; Eason, C. Control Methods: Chemical. In *Rodent Pests and Their Control*, 2nd ed.; Buckle, A., Smith, R., Eds.; CABI International: Wallingford, UK, 2015; pp. 123–154.
22. Stejskal, V.; Vendl, T.; Aulicky, R.; Athanassiou, C. Synthetic and Natural Insecticides: Gas, Liquid, Gel and Solid Formulations for Stored-Product and Food-Industry Pest Control. *Insects* **2021**, *12*, 590. [CrossRef]
23. Frankova, M.; Stejskal, V.; Aulicky, R. Suppression of food intake by house mouse (*Mus musculus*) following ingestion of brodifacoum-based rodenticide bait. *Crop Prot.* **2017**, *100*, 134–137. [CrossRef]
24. Frankova, M.; Stejskal, V.; Aulicky, R. Efficacy of rodenticide baits with decreased concentrations of brodifacoum: Validation of the impact of the new EU anticoagulant regulation. *Sci. Rep.* **2019**, *9*, 16779. [CrossRef] [PubMed]
25. Kappes, P.; Siers, S. Relative acceptance of brodifacoum pellets and soft bait sachets by Polynesian rats (*Rattus exulans*) on Wake Atoll. *Manag. Biol. Invasions* **2021**, *12*, 685–699. [CrossRef]
26. Hohenberger, J.; Friesen, A.; Wieck, S.; Kümmerer, K. In search of the Holy Grail of Rodent control: Step-by-step implementation of safe and sustainable-by-design principles on the example of rodenticides. *Sustain. Chem. Pharm.* **2022**, *25*, 100602. [CrossRef]
27. Shah, J.A.; Vendl, T.; Aulicky, R.; Frankova, M.; Stejskal, V. Gel Carriers for Plant Extracts and Synthetic Pesticides in Rodent and Arthropod Pest Control: An Overview. *Gels* **2022**, *8*, 522. [CrossRef]
28. Villalobos, A.; Schlyter, F.; Birgersson, G.; Koteja, P.; Löf, M. Fear effects on bank voles (Rodentia: Arvicolinae): Testing for repellent candidates from predator volatiles. *Pest Manag. Sci.* **2022**, *78*, 1677–1685. [CrossRef]
29. Sked, S.; Abbar, S.; Cooper, R.; Corrigan, R.; Pan, X.; Ranabhat, S.; Wang, C. Monitoring and Controlling House Mouse, *Mus musculus domesticus*, Infestations in Low-Income Multi-Family Dwellings. *Animals* **2021**, *11*, 648. [CrossRef]
30. Jacob, J.; Imholt, C.; Caminero-Saldaña, C.; Couval, G.; Giraudoux, P.; Herrero-Cófreces, S.; Horváth, G.; Luque-Larena, J.J.; Tkadlec, E.; Wymenga, E. Europe-wide outbreaks of common voles in 2019. *J. Pest Sci.* **2020**, *93*, 703–709. [CrossRef]

31. Luque-Larena, J.J.; Mougeot, F.; Viñuela, J.; Jareño, D.; Arroyo, L.; Lambin, X.; Arroyo, B. Recent large-scale range expansion and outbreaks of the common vole (*Microtus arvalis*) in NW Spain. *Basic Appl. Ecol.* **2013**, *14*, 432–441. [CrossRef]
32. Stojak, J.; Borowik, T.; Górny, M.; McDevitt, A.D.; Wójcik, J.M. Climatic influences on the genetic structure and distribution of the common vole and field vole in Europe. *Mammal Res.* **2019**, *64*, 19–29. [CrossRef]
33. Royer, A.; Montuire, S.; Legendre, S.; Discamps, E.; Jeannet, M.; Lécuyer, C. Investigating the Influence of Climate Changes on Rodent Communities at a Regional-Scale (MIS 1-3, Southwestern France). *PLoS ONE* **2016**, *11*, e0145600. [CrossRef] [PubMed]
34. Baca, M.; Popović, D.; Baca, K.; Lemanik, A.; Doan, K.; Horáček, I.; López-García, J.M.; Bañuls-Cardona, S.; Pazonyi, P.; Desclaux, E.; et al. Diverse responses of common vole (*Microtus arvalis*) populations to Late Glacial and Early Holocene climate changes—Evidence from ancient DNA. *Quat. Sci. Rev.* **2020**, *233*, 106239. [CrossRef]
35. Jeske, K.; Emirhar, D.; García, J.T.; González-Barrio, D.; Olea, P.P.; Fons, F.R.; Schulz, J.; Mayer-Scholl, A.; Heckel, G.; Ulrich, R.G. Frequent *Leptospira* spp. Detection but Absence of Tula Orthohantavirus in *Microtus* spp. Voles, Northwestern Spain. *J. Wildl. Dis.* **2021**, *57*, 733–742. [CrossRef] [PubMed]
36. Leivesley, J.A.; Stewart, R.A.; Paterson, V.; McCafferty, D.J. Potential importance of urban areas for water voles: *Arvicola amphibius*. *Eur. J. Wildl. Res.* **2021**, *67*, 15. [CrossRef]