

我国捕食螨资源发掘到防控应用研究进展*

张 博^{1, 2, 3**} 徐学农^{1, 2, 3***}

(1. 中国农业科学院植物保护研究所, 植物病虫害综合治理全国重点实验室, 北京 100193;

2. 农业农村部天敌重点实验室, 北京 100193;

3. 黄河三角洲农业高新区国家盐碱地综合利用技术创新中心, 东营 257300)

摘 要 捕食螨是生态系统中一类重要的天敌, 在小型吸汁性有害生物如叶螨、蓟马、粉虱等的防控中具有举足轻重的地位, 在减少化学农药使用, 保护生态环境、保障农产品安全上发挥着积极作用。自 20 世纪 50 年代末以来, 我国捕食螨研究与应用取得了诸多创新性成果。本文较为系统地总结了近 70 年来捕食螨从资源开发、生物学研究、产业化发展进程到有害生物治理等方面的成就。最后, 提出捕食螨研发与应用过程中亟需解决的问题及展望。

关键词 植绥螨; 天敌资源; 扩繁与应用; 学科挑战; 展望

Predatory mites in China: From resource exploration to practical application

ZHANG Bo^{1, 2, 3**} XU Xue-Nong^{1, 2, 3***}

(1. State Key Laboratory for Biology of Plant Diseases and Insect Pests, Institute of Plant Protection,

Chinese Academy of Agricultural Sciences, Beijing 100193, China;

2. Key Laboratory of Natural Enemies Insects, Ministry of Agriculture and Rural Affairs, Beijing 100193, China;

3. Agricultural High-tech Industrial Area of the Yellow River Delta, National Center of Technology Innovation for Comprehensive Utilization of Saline-Alkali Land, Dongying 257300, China)

Abstract Predatory mites play a significant role in controlling small, sap-sucking pests, such as spider mites, thrips, and whiteflies. At the same time as the damage caused by these pests intensifies, there is increasing pressure to reduce reliance on chemical control methods due to growing concerns over ecological safety and public health. Consequently, the importance of biological control methods employing the natural enemies of pest mites, particularly predatory mites, has become more prominent. Over the past six decades, China has made significant theoretical and practical advances in the use of predatory mites for biological control purposes. These innovations include research on the biological and ecological characteristics of over 30 species of phytoseiid mites and more than 10 other groups such as Laelapidae, research on the nutritional and reproductive mechanisms of mites, interactions among multiple species, large-scale production, innovations in production technology, and synergistic applications of predatory mites. Alternative prey species for the large-scale production of mites have been identified, including *Carpoglyphus lactis* and *Tyrophagus putrescentiae*. Production methods have transitioned from classical, plant-based systems to non-plant-based systems. There are now production lines for dozens of predatory mite species, including *Phytoseiulus persimilis*, *Neoseiulus californicus*, *Amblyseius orientalis* and *Stratiolaelaps scimitus*. Applications have expanded beyond just the control of spider mites to the control of thrips and whiteflies. This paper offers preliminary reflections on the future development and utilization of predatory mites in China. Recommendations include prioritizing the development of local predatory mite species, intensifying efforts to develop predatory mites that target key pests such as thrips, accelerating the research and development of artificial diets, establishing quality standards for predatory mite products, and

*资助项目 Supported project: 国家重点研发项目 (2023YFD1400600)

**第一作者 First author, E-mail: zhangbo05@caas.cn

***通讯作者 Corresponding author, E-mail: xuxuenong@caas.cn

收稿日期 Received: 2025-08-10; 接受日期 Accepted: 2025-09-03

integrating the application of predatory mites into crop pest and disease control systems.

Key words phytoseiid mites; natural enemy resources; mass rearing and filed applications, challenges; future prospects

1 捕食螨资源挖掘

我国捕食螨的研发,始于 1958 年的植绥螨科调查。此后,其它一些类群如中气门亚目的囊螨科、蟾螨科和厉螨科,恙螨目(绒螨目)前气门亚目的肉食螨科、绒螨科、大赤螨科、长须螨科及蒲螨科(寄生性种类)也相继进行。由于对小型吸汁性有害生物如害螨、蓟马及粉虱等防控的重要地位,植绥螨科捕食螨是目前发现并利用最多的类群。1958-2002 年的 40 余年中共发现植绥螨近 300 种,而近 20 年新种报道放缓,约有 30 余种。目前我国已记录的植绥螨种约占全球已报道 2 800 种的 12%。其中 34 个省(直辖市、自治区)均有植绥螨科物种分布记录,但均匀度不同,东南、西南地区由于有更高的生物多样性而分布更密集。海南发现植绥螨 65 种,约占国内植绥螨种类的 20%,而面积是海南陆地面积近 2 倍的宁夏,发现的植绥螨仅 10 余种,约占总量的 3%。植绥螨种类的分布也有不少差异,有 5 个省级以上分布的物种见表 1(吴伟南等, 2009; 吴伟南和方小端, 2021)。

1.1 具有产业化潜力的捕食螨种类挖掘

我国目前报道有 330 种左右的植绥螨(吴伟南和方小端, 2021),有 30 余种被研究。针对重要的小型吸汁性有害生物,筛选并开发了不同种类的捕食螨(主要来自植绥螨),如针对叶螨的智利小植绥螨 *Phytoseiulus persimilis*,该种于 1975 年由蒲蛰龙和李丽英先生从瑞典引进,此后的 20 余年曾多次引进,以及沃氏新小绥螨 *Neoseiulus womersleyi*(原拟长毛钝绥螨 *Amblyseius pseudolongispinosus*)和加州新小绥螨 *Neoseiulus californicus* 等。针对蓟马的捕食螨有巴氏新小绥螨 *Neoseiulus barkeri* 和剑毛帕厉螨 *Stratiolaelaps scimitus* 等;针对粉虱的有东方钝绥螨 *Amblyseius orientalis* 和津川钝绥螨 *Amblyseius tsugawai* 等。

1.2 捕食螨抗逆及高适合度的品系筛选

通常情况下,捕食螨的自然种群抗逆性不强,因此可利用高温、射线、农药等手段筛选捕食螨的抗逆品系。如西南大学团队利用热驯化手段获得了巴氏新小绥螨耐热品系(Tian 等, 2021);中国农业科学院植物保护研究所利用伽马辐照技术获得了智利小植绥螨的耐热品系。该品系在 38 °C 持续 24 h 的热胁迫下存活率可达 80%,而对照存活率仅为 30%(孔子艺, 2024)。抗药性品系筛选中,西南大学团队经过 21 代抗性筛选,分别获得了抗性 34 倍的巴氏新小绥螨毒死蜱抗性品系和抗性 600 多倍的甲氰菊酯抗性品系(王莉等, 2021);内蒙古农业大学团队经过 30 代的选育,获得了抗性增加 226 倍的巴氏新小绥螨溴氰菊酯抗性品系(张倩等, 2022);福建省农业科学院团队获得了抗性提高 60 倍的胡瓜新小绥螨 *Neoseiulus cucumeris* 抗阿维菌素品系(陈霞等, 2013)。此外,利用伽马射线辐照技术对沃氏新小绥螨繁殖性状的改造,可使辐照品系产卵量升高,同时后代雌雄比 72%也高于正常品系的 65%(王恩东等, 2012)。

2 捕食螨基础生物学研究进展

2.1 基础研究涉及的捕食螨种类

捕食螨基础生物学及生态学的研究主要在 8 个科的 40 余个物种中开展,其中 3/4 的种类又集中于植绥螨科中(表 2),特别是智利小植绥螨、新小绥螨属及钝绥螨属的 10 余个物种。

2.2 捕食螨基础生物学研究进展

2.2.1 生长发育繁殖 所有植绥螨科中,个体发育均经过卵、幼螨、第一若螨、第二若螨及成螨的 5 个阶段。适宜的温湿度条件下,一代大约 5-8 d 左右。每个变态过程需经历较短时间的静息期,之后蜕皮进入下一螨态。Ma 等(2019, 2020a, 2020b)和 Zhang 等(2021)研究了发育

表 1 中国分布较广的植绥螨种类
Table 1 Widely distributed phytoseiid species in China

属 Genus	种 Species	分布区域* Distribution
钝绥螨属 <i>Amblyseius</i>	东方钝绥螨 <i>Amblyseius orientalis</i>	辽宁、河北、山东、江苏、安徽、湖北、江西、湖南、贵州、福建、广东 Liaoning, Hebei, Shandong, Jiangsu, Anhui, Hubei, Jiangxi, Hunan, Guizhou, Fujian, Guangdong
	津川钝绥螨 <i>Amblyseius tsugawai</i>	黑龙江、吉林、辽宁、河北、山西、山东、江苏、安徽、湖北、浙江、江西、湖南、贵州、福建、云南、广东、广西、海南 Heilongjiang, Jilin, Liaoning, Hebei, Shanxi, Shandong, Jiangsu, Anhui, Hubei, Zhejiang, Jiangxi, Hunan, Guizhou, Fujian, Yunnan, Guangdong, Guangxi, Hainan
	江原钝绥螨 <i>Amblyseius eharai</i>	山东、江苏、浙江、福建、江西、湖北、湖南、台湾、广东、广西、香港、海南 Shandong, Jiangsu, Zhejiang, Fujian, Jiangxi, Hubei, Hunan, Taiwan, Guangdong, Guangxi, Hong Kong, Hainan
	拉哥钝绥螨 <i>Amblyseius largoensis</i>	台湾、广东、广西、香港、海南 Taiwan, Guangdong, Guangxi, Hong Kong, Hainan
	草栖钝绥螨 <i>Amblyseius herbicolus</i>	黑龙江、辽宁、甘肃、河南、江苏、四川、湖南、江西、贵州、福建、云南、台湾、广东、广西、海南 Heilongjiang, Liaoning, Gansu, Henan, Jiangsu, Sichuan, Hunan, Jiangxi, Guizhou, Fujian, Yunnan, Taiwan, Guangdong, Guangxi, Hainan
	拉氏钝绥螨 <i>Amblyseius largoensis</i>	辽宁、河北、山东、河南、浙江、江西、湖南、贵州、福建、广东 Liaoning, Hebei, Shandong, Henan, Zhejiang, Jiangxi, Hunan, Guizhou, Fujian, Guangdong
	伊东钝绥螨 <i>Amblyseius ezoensis</i>	四川、浙江、江西、湖南、福建、广东、广西 Sichuan, Zhejiang, Jiangxi, Hunan, Fujian, Guangdong, Guangxi
	坚固钝绥螨 <i>Amblyseius firmus</i>	黑龙江、吉林、内蒙古、河北、河南 Heilongjiang, Jilin, Inner Mongolia, Hebei, Henan
	钝毛钝绥螨 <i>Amblyseius obtuserellus</i>	江苏、安徽、浙江、江西、湖南、福建、广东 Jiangsu, Anhui, Zhejiang, Jiangxi, Hunan, Fujian, Guangdong
新小绥螨属 <i>Neoseiulus</i>	加州新小绥螨 <i>Neoseiulus californicus</i>	广东、海南、四川、云南（应有更多分布） Guangdong, Hainan, Sichuan, Yunnan, and more localities
	巴氏新小绥螨 <i>Neoseiulus barkeri</i>	河北、山东、河南、陕西、安徽、湖北、江西、福建、湖南、台湾、云南、广东、广西、海南、香港 Hebei, Shandong, Henan, Shaanxi, Anhui, Hubei, Jiangxi, Fujian, Hunan, Taiwan, Yunnan, Guangdong, Guangxi, Hainan, Hong Kong
	沃氏新小绥螨 <i>Neoseiulus womersleyi</i>	河北、山东、江苏、安徽、浙江、江西、贵州、福建、广西、台湾 Hebei, Shandong, Jiangsu, Anhui, Zhejiang, Jiangxi, Guizhou, Fujian, Guangxi, Taiwan
	鳞纹新小绥螨 <i>Neoseiulus imbricatus</i>	江苏、江西、湖南、福建、广东、广西、海南、武陵山区 Jiangsu, Jiangxi, Hunan, Fujian, Guangdong, Guangxi, Hainan, Wuling Mountain Area
	真桑新小绥螨 <i>Neoseiulus makuwa</i>	黑龙江、吉林、辽宁、山东、甘肃、江苏、安徽、四川、湖北、江西、湖南、贵州、福建、台湾、云南、广东、广西、海南 Heilongjiang, Jilin, Liaoning, Shandong, Gansu, Jiangsu, Anhui, Sichuan, Hubei, Jiangxi, Hunan, Guizhou, Fujian, Taiwan, Yunnan, Guangdong, Guangxi, Hainan

续表 1 (Table 1 continued)

属 Genus	种 Species	分布区域* Distribution
新小绥螨属 <i>Neoseiulus</i>	长刺新小绥螨 <i>Neoseiulus longispinosus</i>	福建、云南、台湾、广东、广西、香港、海南 Fujian, Yunnan, Taiwan, Guangdong, Guangxi, Hong Kong, Hainan
	古山新小绥螨 <i>Neoseiulus koyamanus</i>	河北、山东、河南、安徽、江西、福建 Hebei, Shandong, Henan, Anhui, Jiangxi, Fujian
	庐山新小绥螨 <i>Neoseiulus lushanensis</i>	山东、河南、浙江、江西、湖南、贵州 Shandong, Henan, Zhejiang, Jiangxi, Hunan, Guizhou
	拟网纹新小绥螨 <i>Neoseiulus subreticulatus</i>	黑龙江、新疆、吉林、辽宁、江西、广东、广西 Heilongjiang, Xinjiang, Jilin, Liaoning, Jiangxi, Guangdong, Guangxi
真绥螨属 <i>Euseius</i>	尼氏真绥螨 <i>Euseius nicholsi</i>	江苏、四川、湖北、重庆、江西、湖南、贵州、福建、台湾、广东、香港、海南、武陵山区 Jiangsu, Sichuan, Hubei, Chongqing, Jiangxi, Hunan, Guizhou, Fujian, Taiwan, Guangdong, Hong Kong, Hainan, Wuling Mountain Area
	芬兰真绥螨 <i>Euseius finlandicus</i>	甘肃、河北、山东、陕西、江苏、西藏 Gansu, Hebei, Shandong, Shaanxi, Jiangsu, Xizang
	卵圆真绥螨 <i>Euseius ovalis</i>	江苏、四川、贵州、江西、福建、云南、台湾、广东、广西、香港、海南 Jiangsu, Sichuan, Guizhou, Jiangxi, Fujian, Yunnan, Taiwan, Guangdong, Guangxi, Hong Kong, Hainan
	爱泽真绥螨 <i>Euseius aizawai</i>	山东、安徽、浙江、福建、云南、台湾、广东、海南 Shandong, Anhui, Zhejiang, Fujian, Yunnan, Taiwan, Guangdong, Hainan
	环形真绥螨 <i>Euseius circellatus</i>	福建、云南、台湾、广东、海南 Fujian, Yunnan, Taiwan, Guangdong, Hainan
	普通真绥螨 <i>Euseius vulgaris</i>	安徽、江西、福建、云南、海南 Anhui, Jiangxi, Fujian, Yunnan, Hainan
盲走螨属 <i>Typhlodromus</i>	竹盲走螨 <i>Typhlodromus (Anthoseius) bambusae</i>	四川、浙江、贵州、福建、台湾、广东、香港、海南 Sichuan, Zhejiang, Guizhou, Fujian, Taiwan, Guangdong, Hong Kong, Hainan
	锯胸盲走螨 <i>Typhlodromus (Anthoseius) serrulatus</i>	辽宁、河北、山东、安徽、浙江、江西、湖南、福建、台湾、广东、广西 Liaoning, Hebei, Shandong, Anhui, Zhejiang, Jiangxi, Hunan, Fujian, Taiwan, Guangdong, Guangxi
	南非盲走螨 <i>Typhlodromus (Anthoseius) transvaalensis</i>	福建、台湾、广东、广西、海南 Fujian, Taiwan, Guangdong, Guangxi, Hainan
	北方盲走螨 <i>Typhlodromus (Anthoseius) borealis</i>	黑龙江、辽宁、江苏、安徽、江西、广西 Heilongjiang, Liaoning, Jiangsu, Anhui, Jiangxi, Guangxi
冲绥螨属 <i>Okiseius</i>	亚热冲绥螨 <i>Okiseius subtropicus</i>	江苏、浙江、江西、贵州、福建、云南、台湾、广东、广西、海南 Jiangsu, Zhejiang, Jiangxi, Guizhou, Fujian, Yunnan, Taiwan, Guangdong, Guangxi, Hainan
肩绥螨属 <i>Scapulaseius</i>	冲绳肩绥螨 <i>Scapulaseius okinawanus</i>	江苏、浙江、安徽、福建、江西、山东、湖南、广东、广西、海南、贵州、云南、香港、台湾 Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Hunan, Guangdong, Guangxi, Hainan, Guizhou, Yunnan, Hong Kong, Taiwan
	纽氏肩绥螨 <i>Scapulaseius newsami</i>	福建、广东、海南、江西、香港 Fujian, Guangdong, Hainan, Jiangxi, Hong Kong

续表 1 (Table 1 continued)

属 Genus	种 Species	分布区域* Distribution
	恩氏肩绥螨 <i>Scapulaseius anuwati</i>	江苏、江西、湖南、福建、台湾、广东、海南 Jiangsu, Jiangxi, Hunan, Fujian, Taiwan, Guangdong, Hainan
	大黑肩绥螨 <i>Scapulaseius oguroi</i>	辽宁、吉林、山东、江苏、安徽、四川、浙江、江西、湖南、贵州、福建、 云南、广东、广西、海南 Liaoning, Jilin, Shandong, Jiangsu, Anhui, Sichuan, Zhejiang, Jiangxi, Hunan, Guizhou, Fujian, Yunnan, Guangdong, Guangxi, Hainan
	亚洲肩绥螨 <i>Scapulaseius asiaticus</i>	江西、湖南、福建、云南、广东、广西、香港、海南 Jiangxi, Hunan, Fujian, Yunnan, Guangdong, Guangxi, Hong Kong, Hainan
小钝伦螨属 <i>Amblyseiulella</i>	拟三叶胶小钝伦螨 <i>Amblyseiulella paraheveae</i>	湖北、江西、湖南、福建、云南、广东、广西 Hubei, Jiangxi, Hunan, Fujian, Yunnan, Guangdong, Guangxi
拟植绥螨属 <i>Paraphytoseius</i>	纤细拟植绥螨 <i>Paraphytoseius cracentis</i>	江西、湖南、贵州、福建、云南、台湾、广东、广西、香港、海南 Jiangxi, Hunan, Guizhou, Fujian, Yunnan, Taiwan, Guangdong, Guangxi, Hong Kong, Hainan
	东方拟植绥螨 <i>Paraphytoseius orientalis</i>	江西、湖南、贵州、福建、云南、台湾、广东、广西、香港 Jiangxi, Hunan, Guizhou, Fujian, Yunnan, Taiwan, Guangdong, Guangxi, Hong Kong
副绥螨属 <i>Paraseiulus</i>	苏氏副绥螨 <i>Paraamblyseius soleiger</i>	黑龙江、新疆、辽宁、河北、山东、青海、江苏 Heilongjiang, Xinjiang, Liaoning, Hebei, Shandong, Qinghai, Jiangsu
似盲走螨属 <i>Typhlodromips</i>	虾夷似盲走螨 <i>Typhlodromus ainu</i>	四川、江西、湖南、贵州、福建、广东、广西、海南 Sichuan, Jiangxi, Hunan, Guizhou, Fujian, Guangdong, Guangxi, Hainan
	丁香似盲走螨 <i>Typhlodromus syzygii</i>	四川、江西、贵州、福建、云南、广东、广西 Sichuan, Jiangxi, Guizhou, Fujian, Yunnan, Guangdong, Guangxi
植绥螨属 <i>Phytoseius</i>	香港植绥螨 <i>Phytoseius hongkongensis</i>	山东、江苏、湖北、江西、贵州、福建、云南、台湾、广东、广西、香港、 海南 Shandong, Jiangsu, Hubei, Jiangxi, Guizhou, Fujian, Yunnan, Taiwan, Guangdong, Guangxi, Hong Kong, Hainan
	油桐植绥螨 <i>Phytoseius aleuritius</i>	河北、山东、河南、湖北、福建 Hebei, Shandong, Henan, Hubei, Fujian
	柯氏植绥螨 <i>Phytoseius coheni</i>	江西、贵州、福建、云南、台湾、广东、广西、香港、海南 Jiangxi, Guizhou, Fujian, Yunnan, Taiwan, Guangdong, Guangxi, Hong Kong, Hainan
	长毛植绥螨 <i>Phytoseius crinitus</i>	江西、云南、台湾、广东、广西、香港、海南 Jiangxi, Yunnan, Taiwan, Guangdong, Guangxi, Hong Kong, Hainan
	闽植绥螨 <i>Phytoseius fujianensis</i>	贵州、福建、广东、广西、海南 Guizhou, Fujian, Guangdong, Guangxi, Hainan
	日本植绥螨 <i>Phytoseius nipponicus</i>	辽宁、山东、甘肃、河南、江苏、四川、湖北、浙江、江西、湖南、福建、 云南、广东、广西、海南 Liaoning, Shandong, Gansu, Henan, Jiangsu, Sichuan, Hubei, Zhejiang, Jiangxi, Hunan, Fujian, Yunnan, Guangdong, Guangxi, Hainan

*分布区按省会纬度从北向南排列。

*Distribution zones are arranged from north to south according to the latitude of provincial capitals.

表 2 生物生态学研究涉及的重要捕食螨物种

Table 2 Key predatory mite species involved in biological and ecological studies

科 Family	属 Genus	种 Species
植绥螨科 Phytoseiidae	小植绥螨属 <i>Phytoseiulus</i>	智利小植绥螨 <i>Phytoseiulus persimilis</i>
	钝绥螨属 <i>Amblyseius</i>	东方钝绥螨 <i>Amblyseius orientalis</i> , 津川钝绥螨 <i>Amblyseius tsugawai</i> , 江原钝绥螨 <i>Amblyseius eharae</i> , 拉哥钝绥螨 <i>Amblyseius largoensis</i> , 安德森钝绥螨 <i>Amblyseius andersoni</i> , 海南钝绥螨 <i>Amblyseius hainanensis</i> , 斯氏钝绥螨 <i>Amblyseius swirskii</i>
	新小绥螨属 <i>Neoseiulus</i>	加州新小绥螨 <i>Neoseiulus californicus</i> , 巴氏新小绥螨 <i>Neoseiulus barkeri</i> , 沃氏新小绥螨 <i>Neoseiulus womersleyi</i> , 双尾新小绥螨 <i>Neoseiulus bicaudus</i> , 伪新小绥螨 <i>Neoseiulus fallacis</i> , 乡野新小绥螨 <i>Neoseiulus agresitis</i> , 狗尾草新小绥螨 <i>Neoseiulus setarius</i>
	真绥螨属 <i>Euseius</i>	爱泽真绥螨 <i>Euseius aizawai</i> , 尼氏真绥螨 <i>Euseius nicholsi</i> , 栗真绥螨 <i>Euseius castaneae</i> , 芬兰真绥螨 <i>Euseius finlandicus</i> , 卵圆真绥螨 <i>Euseius ovalis</i>
	盲走螨属 <i>Typhlodromus</i>	竹盲走螨 <i>Typhlodromus bambusae</i> 、锯胸盲走螨 <i>Typhlodromus serrulatus</i> 、南非盲走螨 <i>Typhlodromus (Anthoseius) transvaalensis</i>
	冲绥螨属 <i>Okiseius</i>	亚热冲绥螨 <i>Okiseius subtropicus</i>
	肩绥螨属 <i>Scapulaseius</i>	冲绳肩绥螨 <i>Scapulaseius okinawanus</i> , 纽氏肩绥螨 <i>Scapulaseius newsami</i>
	副绥螨属 <i>Paraseiulus</i>	苏氏副绥螨 <i>Paraamblyseius soleiger</i>
	钝近走螨属 <i>Paraphylloseius</i>	檬钝近走螨 <i>Amblydromalus limonicus</i>
	静走螨属 <i>Galendromus</i>	西方静走螨 <i>Galendromus occidentalis</i>
	似前锯绥螨属 <i>Proprioseiopsis</i>	墨西哥似前锯绥螨 <i>Proprioseiopsis mexicanus</i> (同物异名 Synonym: 少毛钝绥螨 <i>Amblyseiulus asetis</i>)
囊螨科 Ascidae	蠃螨属 <i>Blattisocius</i>	等钳蠃螨 <i>Blattisocius dentriticus</i>
蠃螨科 Blattisociidae	毛绥螨 <i>Lasioseius</i>	管原毛绥螨 <i>Lasioseius sugawarai</i> , 日本毛绥螨 <i>Lasioseius japonicus</i> , 梭形毛绥螨 <i>Lasioseius scapulatus</i>
厉螨科 Laelapidae	帕厉螨属 <i>Stratiolaelaps</i>	剑毛帕厉螨 <i>Stratiolaelaps scimitus</i>
长须螨科 Stigmaeidae	神蕊螨属 <i>Agistemus</i>	具瘤神蕊螨 <i>Agistemus exsertus</i>
绒螨科 Trombidiidae	异绒螨属 <i>Allothrombium</i>	小枕异绒螨 <i>Allothrombium pulvinum</i> , 卵形异绒螨 <i>Allothrombium ovatum</i>
大赤螨科 Anystidae	大赤螨属 <i>Anystis</i>	圆果大赤螨 <i>Anystis baccarum</i>
肉食螨科 Cheyletidae	肉食螨属 <i>Cheyletus</i>	马六甲肉食螨 <i>Cheyletus malaccensis</i> , 转开肉食螨 <i>Cheyletus carnifex</i> , 普通肉食螨 <i>Cheyletus eruditus</i>

过程中各螨态的形态变化。与昆虫变态生理变化过程稍有差别,植绥螨个体在发育过程中,尚未发现传统保幼激素的参与,但发现在智利小植绥螨幼螨阶段,保幼激素通路相关基因 *PpJHAMT* 和 *PpKr-h1* 表达量升高。蜕皮激素受体基因 *PpEcR* 在智利小植绥螨蜕皮阶段可能起着关键作用(范丽娜, 2024)。

个体生长发育中受到诸多环境因子的影响,温度因素已受到特别关注。数种捕食螨供以不同猎物时的发育繁殖研究已有大量报道,如植绥螨科的智利小植绥螨(吴伟南等, 1982; 郭玉杰和董慧芳, 1987; 宫亚军等, 2017)、加州新小绥螨(崔琦和李庆, 2015; 贾静静等, 2018, 2019a, 2019b)、巴氏新小绥螨(黄建华等, 2012; Xia *et al.*, 2012)、胡瓜新小绥螨(经佐琴等, 2001; 李宁等, 2002; 赵云龙等, 2016)、双尾新小绥螨 *Neoseiulus bicaudus* (Li *et al.*, 2015)、伪钝绥螨 *Amblyseius fallacis* (张乃鑫和孔建, 1987; 孙月华等, 2010)、安德森钝绥螨 *Amblyseius andersoni* (Li *et al.*, 2019)、尼氏真绥螨 *Euseius nicholsi* (鄧军锐等, 1992; Wang *et al.*, 2014)、卵圆真绥螨 *Euseius ovalis* (于静静等, 2018)、墨西哥似前锯绥螨 *Proprioseiopsis mexicanus* (Huang *et al.*, 2014)和竹盲走螨 *Typhlodromus bambusae* (刘怀等, 2002)等。此外,也包括其它科的捕食螨,如肉食螨科的普通肉食螨 *Cheyletus eruditus* (夏斌等, 2005)与马六甲肉食螨 *Cheyletus malaccensis* (Yin *et al.*, 2019; Sun *et al.*, 2020)、吸螨科的热带吸螨 *Bdella tropica* (Chen *et al.*, 2011)、囊螨科的等钳蠃螨 *Blattisocius dentriticus* (郭蕾等, 2014)以及蠃螨科的日本毛绥螨 *Lasioseius japonicus* (Zhang *et al.*, 2022)等。

植绥螨适宜的生长发育繁殖温度在 25-28 °C 左右,高温耐受能力不强。西南大学研究了高温迭代筛选得到的巴氏新小绥螨耐高温品系,通过鉴定到的 4 个 MAPK (Mitogen-activated protein kinase) 通路基因,发现它们被激活后会促进高温适应型的巴氏新小绥螨对高温的耐受性(Tian *et al.*, 2023a)。在加州新小绥螨中也发

现有类似现象(Tian *et al.*, 2023b)。

2.2.2 食性、捕食选择性及功能反应 捕食螨可捕食多类群的小型有害生物,包括叶螨、蓟马、粉虱、木虱(Liu *et al.*, 2019; Fu *et al.*, 2024)、蚜虫(张智强, 1988)及线虫(周万琴等, 2012)等。McMurtry 和 Croft (1997)和 McMurtry 等(2013)根据植绥螨的食性,将其分为四大类,包括叶螨的专食性捕食者(第 I 类),叶螨的选择性捕食者(第 II 类),多食性捕食者(第 III 类)及嗜食花粉的捕食者(第 IV 类)。吴伟南等(2008)列举了国内植绥螨这四类食性的一些重要种类。Liu 等(2017)通过对多种植绥螨颚体结构的研究分析发现食性与颚体特别是口器结构相关,并与上述四类食性的划分较为吻合。

植绥螨无眼,通过须肢及第一对足上的触觉器官及感器,识别猎物为害植物后释放的次生代谢产物及猎物本身、排泄物、分泌物等完成猎物定位(董慧琴等, 1995; Munawar *et al.*, 2023)。Su 等(2021, 2023)研究了 3 种不同食性捕食螨须肢及足 I 跗节上的感器,分析了感器的类型及数量,并提出足 I 跗节感器新的标记方法。Wu 等(2023)和 Zhou 等(2023)分别研究了巴氏新小绥螨和智利小植绥螨嗅觉相关 OBP 和 NPC2 基因的表达与功能,推测捕食行为与化学信号识别有关。

此外,捕食螨对猎物不同发育阶段存在选择性。可能由于虫体大小的原因,植绥螨大多对害虫(螨)的卵、幼若虫(螨)表现更强的选择性,但不同种的选择性有差别,如芬兰真绥螨 *Euseius finlandicus* 对山楂叶螨 *Tetranychus viennensis* 卵有明显的正喜好性(张新虎, 1993);而与卵及幼螨相比,加州新小绥螨更喜食朱砂叶螨 *Tetranychus cinnabarinus* 的若螨(蒋洪丽等, 2015)。即使是第 III 类多食性捕食螨,虽然可同时捕食如害螨、蓟马及粉虱,包括同类群中的不同种类,其选择性也有差别。双尾新小绥螨当烟粉虱 *Bemisia tabaci* 与土耳其斯坦叶螨 *Tetranychus turkestanii* 共发时,对后者的选择性更强(韩国栋等, 2020);江原钝绥螨 *Amblyseius eharai* 在柑橘全爪螨 *Panonychus citri*、柑橘粉虱

Dialeurodes citri 与黄胸蓟马 *Thrips hawaiiensis* 共存时,更喜取食柑橘全爪螨(李晓杨等,2021); 津川钝绥螨 *Amblyseius tsugawai* 喜食二斑叶螨 *Tetranychus urticae* 幼螨和烟粉虱卵,当两者同时提供给津川钝绥螨时,其不表现明显的取食倾向性(Yang et al., 2019)。

功能反应是评价捕食者捕食量的重要指标之一,多种植绥螨的功能反应均有研究。包括一种捕食螨对一种猎物,一种捕食螨对几种猎物(李新义等,2001),几种捕食螨对一种猎物(韦德卫等,1995;蒋洪丽等,2015),以及一些生物因素(杨康等,2015;Li and Zhang, 2020)与非生物因素如温度(辛天蓉等,2013;尚素琴等,2016;朱安迪等,2022)对功能反应的影响等。涉及到的猎物包括农林业上的重要害螨,如叶螨(周爱农和张孝羲,1989;张新虎,1993;Song et al., 2016)、全爪螨(江汉华等,1988;何永福等,1993;甘明等,2001;凌鹏等,2008)、瘿螨(程立生等,2005)、跗线螨(李佳敏等,2003;Li et al., 2018;Zhang et al., 2023),害虫,如蓟马(郅军锐和任顺祥,2006;吴圣勇等,2009;Yao et al., 2014;黄伟康等,2022;Zhu et al., 2023)、粉虱(杨静逸等,2018)、木虱(Fu et al., 2024)以及贮粮害虫(Sun et al., 2023)等多种小型吸汁性有害生物。

2.2.3 多物种及与环境因子互作 由于生态系统的复杂性,一种害虫与一种天敌的简单互作关系在指导防控中常暴露现实的局限性,因此生态系统中的植物、害虫、天敌甚至微生物等间的互作则逐渐引起科研工作者的重视。害虫和害螨多有同发共发特性,因此防治时同时释放几种天敌也较为常见。研究不同种天敌及猎物存在情况下的兼性捕食作用(Intraguild predation, IGP),对指导害虫防控具备极大的现实意义。多数研究表明,在无猎物的情况下,捕食螨间或捕食螨与天敌昆虫间都会发生 IGP,而个别种类植绥螨还有更倾向攻击自身的幼体而发生自残,却对异种个体的幼体捕食量小的现象(郭建晗等,2016);当猎物存在特别是高密度的情况下,通常会削弱 IGP(Zhang et al., 2014;卢塘飞等,2021),但

也会受到捕食者对猎物喜好性的影响(卢塘飞等,2021)。当安德森钝绥螨及巴氏新小绥螨与截形叶螨 *Tetranychus truncatus* 与共存时,巴氏新小绥螨由于更喜食叶螨而减少对安德森钝绥螨的猎食,而安德森钝绥螨却表现相反的捕食行为,而在集团内表现出更加强势的地位(Chi et al., 2023)。Liu 等(2023)研究巴氏新小绥螨与塔六点蓟马 *Scolothrips takahashii* 在缺乏猎物时,互为集团内猎物,并可促进对方存活期延长及繁殖。

化学农药减量使用后,昆虫病原微生物在害虫防治中扮演了重要角色,与天敌的互作也倍受关注。巴氏新小绥螨由于较厚的背腹板,相较于蓟马,难以被白僵菌的孢子侵染(Wu et al., 2018);对二斑叶螨强致病性的白僵菌品系对 5 种植绥螨没有致病性(Wu et al., 2016b)。巴氏新小绥螨可取食白僵菌的孢子,孢子 24 h 后在其体内失活(Wu et al., 2016a),但巴氏新小绥螨取食经白僵菌孢子喷雾处理 12 h 西花蓟马 *Frankliniella occidentalis* 初孵幼虫后,可能是因为白僵菌毒素的作用,却对捕食螨有一定的负面影响(Wu et al., 2015)。除了表皮对孢子的抵抗外,Niu 等(2023)发现巴氏新小绥螨的 *NbSpz-1* 基因与抵抗白僵菌侵染有关,当这个基因被敲除后,巴氏新小绥螨对白僵菌侵染的抗性会降低。

微生物在调节植物、害虫及其天敌三个营养级中发挥着关键作用。Yan 等(2025)通过 16S rRNA 测序方法,研究了植物(芸豆、黄瓜和茄子)、二斑叶螨和智利小植绥螨食物链中三级营养系统中的微生物动态,发现不同营养级间的微生物群落存在显著差异,各营养级微生物群落极少来源于其前一营养级,假单胞菌属 *Pseudomonas* 和芽孢杆菌属 *Bacillus* 为跨营养级共享菌。确定性过程在塑造各营养级内生菌群落中起关键作用。3 种植物的叶片微生物群落存在差异,而叶螨携带的微生物群落则高度相似。此外,茄子植株上智利小植绥螨的微生物群落与芸豆和黄瓜上的存在显著差异。甲基杆菌 *Methylobacterium* 和寡氧单胞菌 *Stenotrophomonas* 的丰度差异与不同植物上智利小植绥螨的适合度呈现明显相

关性。该研究说明不同营养级的微生物群落呈现复杂的动态关系。

2.3 植绥螨特殊的生殖特征及其分子机理

植绥螨独特的假产雄孤雌生殖方式一直倍受关注,国内发掘出的植绥螨科物种多为这种生殖方式。交配是产卵的必要条件,雌螨必须交配方能产卵,雄螨亦由受精卵发育而来,但却为单倍体。目前仅发现乡野新小绥螨 *Neoseiulus agresitis* 为孤雌产雌生殖 (Fu et al., 2025), 该种尚未发现有雄螨。

植绥螨科捕食螨后代性比相对稳定,除智利小植绥螨雌性比可达到 80% 外,其它植绥螨后代雌性比多为 67% 左右。一些生物或非生物因素均可能影响到后代性比,如交配时长 (徐学农和梁来荣, 1994; Lv et al., 2019)、食物源及取食经历 (Lu et al., 2022)、变温及光周期 (胡昊旻等, 2020) 等多种因素对性别分化均有作用。

随着分子生物学技术的发展,与生殖及性别分化等相关的重要基因也得以研究,如智利小植绥螨的 *RpL11*、*RpS2*、*transformer 2* 基因 (Bi et al., 2019)、*doublesex* 基因 (Wang et al., 2022b)、*sexlethal* 基因 (Li et al., 2023) 及多种植绥螨的 *Vg* 基因 (Jiang et al., 2020; Wang et al., 2022a; Zhu et al., 2024) 等。以上研究通过分析生殖相关基因的功能,以期明确对性别调控的作用及特殊的生殖机制。此外,植绥螨雌、雄成螨生殖系统的结构也获得解析,包括精子传递过程和受精卵发育等 (Jiang et al., 2019; Huang et al., 2024)。

2.4 植绥螨共生菌及肠道微生物

昆虫共生菌研究的兴起也影响了螨类共生微生物的研究。近十年来,植绥螨共生菌及肠道微生物也广受关注。*Wolbachia* 在昆虫及叶螨中发挥着调控生殖等作用,但未发现其在我国植绥螨科物种中存在。目前报道的一些可以影响捕食螨适合度的有益菌和致病菌,或来自于环境与猎物,可能本身就存在于螨体中并参与多项生命活动等。

捕食螨体内微生物群落组成在不同程度上

由猎物种类影响。当猎物在二斑叶螨与替代猎物粉螨间切换时,斯氏钝绥螨 *Amblyseius swirskii* 的细菌群落 β -多样性受到显著影响,而东方钝绥螨与巴氏新小绥螨在微生物群落结构上却没有显著变化 (Yan et al., 2024a)。类似的,加州新小绥螨与巴氏新小绥螨取食人工饲料的细菌多样性与取食花粉与二斑叶螨的显著不同,但无论取食上述何种食物, *Bosea* sp. 都是在这两种捕食螨中均可检测出来的核心微生物。而这两种捕食螨取食同样的人工饲料其细菌多样性也显著不同 (Yan et al., 2021)。

在植绥螨中,国际上最早发现智利小植绥螨的专性致病菌 *Acaricomes phytoseiuli* 广泛存在于欧洲商业化产品和实验室种群中 (Gols et al., 2007), 此菌最近在国内捕食螨中也有发现 (Xie et al., 2022)。感染该菌的捕食螨种群 3-5 d 即可死亡一半以上,即使存活的雌螨繁殖力及捕食能力也显著下降。该菌富集于肠道与卵巢中,智利小植绥螨受感染 1 d 后,有 4 个基因 (*tok*、*HPB*、*DUOX* 和 *Peroxidase*) 显著上调,说明这些基因可能参与了智利小植绥螨应对细菌性病害的先天免疫反应 (Chen et al., 2025)。

一些共生微生物对寄主自身适合度及抗逆性方面有突出作用。智利小植绥螨中成功分离到的细菌 *Stenotrophomonas maltophilia*, 此菌虽对智利小植绥螨的适合度,包括存活、发育历期、繁殖和寿命都没有显著影响,但可明显降低受致病菌 *Acaricomes phytoseiuli* 感染的风险,与对照相比死亡率减少 20% (Yan et al., 2024b)。

2.5 植绥螨的基因组学研究

近十年来,基因组学在基础研究中得到飞速发展。随着测序技术的完善,仅植绥螨科捕食螨中已有超过 10 个物种获得了线粒体基因组的序列 (津川钝绥螨、斯氏钝绥螨、沃氏新小绥螨、加州新小绥螨、江原钝绥螨、巴氏新小绥螨、东方钝绥螨、胡瓜新小绥螨、尼氏真绥螨和智利小植绥螨), 其中胡瓜新小绥螨 (Zhang et al., 2019)、智利小植绥螨 (Zhou et al., 2025) 和加州新小绥螨 (Liu et al., 2025) 这 3 个物种还完

成了全基因组序列的组装和注释。目前整个植绥螨科共完成了 4 个物种(包括西方盲走螨 *Typhlodromus occidentalis*) 的基因组, 其中 3 个都来自中国的研究团队, 也说明国内的蜱螨学团队为整个学科做出的世界贡献。

在挖掘功能基因与性状关联的研究中, 很多基因家族都有所涉及, 如激素合成基因(盛瑞瑞, 2021)、神经肽受体基因、离子通道基因(冯小天, 2024)等。其中最多的就是与农药相关的细胞通道基因和解毒基因, 它们作为捕食螨耐药性的分子机制被首先拿来研究, 包括重要 P450 基因家族(Cong *et al.*, 2016; Tian *et al.*, 2020; Yu *et al.*, 2024), 谷胱甘肽转移酶家族(Tian *et al.*, 2020)等。此外还有一些细胞中保守的 MAPK 通路基因(Tian *et al.*, 2023a), 热激蛋白 HSP 基因家族等也都在植绥螨中有所研究(Chen *et al.*, 2015; Tian *et al.*, 2020, 2021; Kong *et al.*, 2025)。

3 规模化扩繁与生产

20 世纪 70 年代末到 80 年代初, 捕食螨生产起步于实验室瓶瓶罐罐的小种群扩繁。当国际上有成功使用替代猎物规模化饲养多食性捕食螨的先例后, 张智强教授在 1995 年由国际农业和生物科学研究中心国际昆虫研究所与复旦大学生命科学院联合举办的“国际农业螨类讲习班”上, 率先提出国内要开展捕食螨的产业化。在他的积极推动下, 国内捕食螨规模化生产逐渐进入快车道。至此, 捕食螨生产及产业化发展在我国已有近 30 年的历史。

3.1 主要商业化捕食螨品种及产业化技术

目前, 我国可以生产智利小植绥螨、巴氏新小绥螨、加州新小绥螨、东方钝绥螨、双尾新小绥螨、墨西哥似前锯绥螨、剑毛帕厉螨、胡瓜新小绥螨、中华甲蒲螨 *Pyemotes zhonghuaajia* (寄生性) 和马六甲肉食螨等 10 余种捕食螨。对于叶螨专食性捕食螨(第 I 类)而言, 目前仅能利用靶标猎物饲养。第 II-IV 类捕食螨, 除了早期利用腐食酪螨 *Tyrophagus putrescentiae* 饲养外,

当前又开发了粉螨科 *Acaridae*、果螨科 *Carpoglyphidae* 及温特螨科 *Winterschmidtidae* 等多个种类的替代猎物。如利用甜果螨 *Carpoglyphus lactis* 饲养东方钝绥螨(盛福敬等, 2014; 王伯明等, 2014, 2015); 侯飞等(2022)、Zhu 等(2023)分别利用温特螨科贝氏小奥林螨 *Oulenziella bakeri* 饲养草栖钝绥螨 *Amblyseius herbicolus* 与加州新小绥螨, 发现此螨均为两种捕食螨优质的替代猎物, 极为适合大量生产。此外, 在替代猎物的饲料中添加氨基酸及糖等, 通过猎物传递营养物质可显著地提高捕食螨的繁殖与生产效率(Huang *et al.*, 2013; 杨康等, 2015; Lv *et al.*, 2016); 在花粉中添加酵母也会促进尼氏真绥螨的繁殖效率(Jin *et al.*, 2023)。

虽然使用人工饲料可减少生产环节, 有效提高捕食螨生产的自动化水平及商业效率, 但其一直是国际天敌产业化过程中的瓶颈。Song 等(2019)研究了利用人工饲料连续饲养加州新小绥螨; 中国农业科学院植物保护研究所捕食螨团队为此也做了大量尝试, 研究了叶螨及捕食螨的营养需求及上百种人工饲料配方(He *et al.*, 2019a, 2019b; 何永娟等, 2019; 刘静月等, 2019), 包括加入益生菌等, 还研究了叶螨及捕食螨的口器结构与取食方式(贾冰红, 2016; 刘珊, 2017), 以及人工饲料的型制等。目前国内外在捕食螨人工饲料研究领域内均无突破性进展。

3.2 捕食螨产品的贮藏技术

捕食螨产品是活体生物, 不耐贮藏, 通常需要立即使用。但生产出来的产品有时并不能马上在田间释放, 冷藏是最常采取的方法。冷藏温度与时间对捕食螨的适应性有差异(刘伯明等, 2012)。12 °C 条件下, 双尾新小绥螨可贮藏 35 d, 对其捕食量、寿命及繁殖等没有显著影响(唐思琼等, 2021); 中华甲蒲螨在相似条件下有类似结果(He *et al.*, 2019), 但释放后在田间的定殖效率等尚未开展细致研究。

3.3 产业化过程中存在的问题

随着产业规模的扩大及生产时间的延长, 研

究者也发现捕食螨会受到病原菌污染及在不同捕食螨种间传播等问题 (Xie *et al.*, 2022)。此外, 由于捕食螨体型小, 肉眼难以识别, 多数情况下只有通过制片方能准确鉴定种类, 生产车间内常存在多种捕食螨互相串种的问题, 即目标饲养种类被其他捕食螨种类污染甚至逐渐被替代等情况屡见不鲜。因此捕食螨的标准化生产流程以及天敌商品质量监测与监督问题亟待改善。

4 捕食螨在有害生物防控中的应用

20 世纪 70 年代末到 80 年代初, 对捕食螨的利用主要体现在田间保护及实验室小规模饲养与释放 (董慧芳等, 1986; 张乃鑫等, 1987; 张守友等, 1992)。我国南方曾广泛种植霍香蓟助殖捕食螨防治柑橘害螨等, 取得了很好的防治效果 (麦秀慧等, 1984; 吴伟南和蓝文明, 1988; 周程爱等, 1994; 黄明度, 2008; 黄明度和欧阳革成, 2025)。随着国际捕食螨产业化及商品化的发展, 中国捕食螨产业化也积极跟进, 使得大规模田间应用成为可能。

首先, 捕食螨的防控对象从早期的少数几种叶螨扩大到多种害螨、害虫及线虫等有害生物。这些防控对象包括二斑叶螨、朱砂叶螨、土耳其斯坦叶螨、截形叶螨、山楂叶螨、六点始叶螨 *Eotetranychus sexmaculatus* (贾静静等, 2019c)、苹果全爪螨 *Panonychus umli*、柑橘全爪螨、瘿螨、跗线螨, 麦长腿蜘蛛 *Petrobia latus* 与麦圆蜘蛛 *Penthaleus major*、西花蓟马、八节黄蓟马 *Thrips flavidulus*、茶棍蓟马 *Dendrothrips minowai*、粉虱 (烟粉虱)、木虱和线虫等。

其次, 可保护的作物从少数几种果树扩展到多种生境下的果蔬茶花等多种农经作物。从保护地到更大范围的大田作物, 如保护地草莓、甜樱桃、桃树、西瓜、番茄、辣椒、茄子、黄瓜等, 大田作物如苹果、柑橘、各种莓果、茶树、棉花、烟草、薄荷、菜豆、小麦等, 甚至包括橡胶 (Chen *et al.*, 2023) 等经济林。

再次, 有害生物防控技术从“一虫一技”协同并延伸到“多虫多技”。例如, 利用白僵菌与捕食螨, 如剑毛帕厉螨 (Sun *et al.*, 2018; Zhang

et al., 2021) 和巴氏新小绥螨 (Wu *et al.*, 2017), 兼顾植物上与土壤中的蓟马不同虫态开展的立体防控。中国农业科学院植物保护研究所开发的“温室大棚蔬菜上蓟马立体防控技术”被列入农业部 (现农业农村部) 科教司“农业轻简化实用技术汇编”。花粉不仅可用于捕食螨的生产, 田间投放还能帮助捕食螨早期定殖并建立种群, 从而增强有害生物的防控 (Liu and Zhang, 2017)。联合应用捕食螨 (檬钝近走螨 *Amblyseius herbicolus* 或胡瓜新小绥螨 *Amblydromalus limonicus*) 与白僵菌或花粉, 可显著抑制马铃薯木虱 *Bactericera cockerelli* 的种群密度 (Liu *et al.*, 2019)。Fang 等 (2018) 利用捕食螨与生物农药苦参碱共同防控柑橘害虫害螨 (木虱与柑橘全爪螨) 也取得了较好的效果。

5 问题与展望

虽然我国 70 年捕食螨发展之路硕果累累, 但捕食螨领域从研究到应用的链条上仍存在不少机遇与挑战。首先, 捕食螨类群的生物资源发掘仍待深入。“巧妇难为无米之炊”, 好米方可煮出好饭。科研工作者应继续加大国内本土捕食螨品种的开发, 同时关注各生态环境 (如盐碱地、荒漠区、干旱/半干旱区等特殊生境) 中特定捕食螨种类。持续跟进国内频发重发的有害生物如蓟马和粉虱的捕食螨种类发掘。捕食螨资源不仅仅指植绥螨科, 也包括其它如大赤螨科等种类的开发。

相比我国害虫防控的实际需求, 捕食螨生产仍有极大的拓展空间, 因此还要继续加快捕食螨产业化生产步伐。不仅需要加快人工饲料的研发, 提高机械化自动化生产水平, 还要开发更适合于释放的产品形式及释放器具等, 同时持续推进捕食螨产品质量标准的制订。

在人工智能科技浪潮席卷世界的当下, 农业工作者要开放思路, 积极探索天敌的精准化应用。以构建生态大模型为基础, 加快人工智能在害虫防控治理中的落地应用。优化捕食螨释放的精准决策, 协调捕食螨与多种防控措施的集成, 为农业有害生物提供定制化防治策略。

参考文献 (References)

- Bi SJ, Lv JL, Xu J, Shi DY, Wang ED, Li GT, Xu XN, 2019. RNAi mediated knockdown of RpL11, RpS2, and tra-2 led to reduced reproduction of *Phytoseiulus persimilis*. *Experimental and Applied Acarology*, 78(4): 505–520.
- Chen JY, Zheng LJ, Ye ZP, Wang JY, Zhang FP, Fu YG, Zhang CH, 2023. Evaluation of the predatory mite *Neoseiulus barkeri* against spider mites damaging rubber trees. *Insects*, 14(7): 648.
- Chen W, Li DS, Zhang M, Zhao YL, Wu WJ, Zhang GR, 2015. Cloning and differential expression of five heat shock protein genes associated with thermal stress and development in the polyphagous predatory mite *Neoseiulus cucumeris* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, 67(1): 65–85.
- Chen X, Zhang YX, Zhang YP, Ji J, Lin JZ, 2011. Influence of temperature on development of *Bdella tropica* Atyeo (Acari: Bdellidae) with *Tetranychus urticae* Koch (Acari: Tetranychidae) as its prey. *International Journal of Acarology*, 37(Suppl 1): 34–39.
- Chen X, Zhang YX, Ji J, Lin JZ, Sun L, 2013. Study on cross-resistance of Abamectin-resistant strain of *Neoseiulus cucumeris*. *Fujian Agricultural Science and Technology*, 1: 67–69. [陈霞, 张艳璇, 季洁, 林坚贞, 孙莉, 2013. 胡瓜新小绥螨抗阿维菌素品系的交互抗性研究. 福建农业科技, 1: 67–69.]
- Chen Y, Wang ED, Xu XN, Zhang B, 2025. The immune response of *Phytoseiulus persimilis* (Acari: Phytoseiidae) to the bacterial pathogen *Acaricomex phytoseiuli*. *Experimental and Applied Acarology*, 95(1): 1.
- Cheng LS, Zhang XM, Sha LH, Lu AN, Chen P, 2005. Functional and numerical response of *Amblyseius largoensis* to *Aceria litchi*. *Chinese Journal of Tropical Crops*, 26(1): 52–59. [程立生, 张先敏, 沙林华, 卢安能, 陈攀, 2005. 拉哥钝绥螨对荔枝瘤瘿螨的功能与数值反应. 热带作物学报, 26(1): 52–59.]
- Chi YM, Li YJ, Liu JT, Fu XT, Meng RX, 2023. Diet type and prey preference affect intraguild predation between *Amblyseius andersoni* and *Neoseiulus barkeri*. *Systematic and Applied Acarology*, 28(8): 1415–1428.
- Cong L, Chen F, Yu SJ, Ding LL, Yang J, Luo R, Tian HX, Li HJ, Liu HQ, Ran C, 2016. Transcriptome and difference analysis of fenpropathrin resistant predatory mite, *Neoseiulus barkeri* (Hughes). *International Journal of Molecular Sciences*, 17(6): 704.
- Cui Q, Li Q, 2015. Effects of temperature on the parameters of experimental populations of *Neoseiulus californicus* (Acari: Phytoseiidae) feeding on *Tetranychus cinnabarinus*. *Plant Protection*, 41(3): 40–44. [崔琦, 李庆, 2015. 温度对以朱砂叶螨为食的加州新小绥螨实验种群参数的影响. 植物保护, 41(3): 40–44.]
- Dong HF, Guo YJ, Niu LP, 1986. Study on the control of two-spotted spider mite on four greenhouse ornamental plants using *Phytoseiulus persimilis*. *Biological Control*, 2(2): 59–62. [董慧芳, 郭玉杰, 牛离平, 1986. 应用智利小植绥螨防治温室四种花卉上二斑叶螨的研究. 生物防治通报, 2(2): 59–62.]
- Dong HQ, Yang YY, Liang LR, 1995. A comparison of the locating responses of two phytoseiid mites (*Tetranychus cinnabarinus*) to kairomone of red spider mite. *Journal of Fudan University (Natural Science Edition)*, 34(4): 445–450. [董慧琴, 杨琰云, 梁来荣, 1995. 二种植绥螨对朱砂叶螨利他素定位反应的比较. 复旦学报(自然科学版), 34(4): 445–450.]
- Fan LN, 2024. Preliminary study on the function of juvenile hormone and ecdysteroids receptor and signaling gene in *Phytoseiulus persimilis*. Master dissertation. Hefei: Anhui Agricultural University. [范丽娜, 2024. 智利小植绥螨保幼及蜕皮激素受体与信号基因功能初探. 硕士学位论文. 合肥: 安徽农业大学.]
- Fang XD, Ouyang GC, Lu HL, Guo MF, Wu WN, 2018. Ecological control of citrus pests primarily using predatory mites and the bio-rational pesticide matrine. *International Journal of Pest Management*, 64(3): 262–270.
- Feng XT, 2024. Olfactory function of ionotropic receptors IR25a and IR5 in *Neoseiulus barkeri*. Master dissertation. Chongqing: Southwest University. [冯小天, 2024. 巴氏新小绥螨离子型受体 NbarIR25a 和 NbarIR5 的嗅觉功能研究. 硕士学位论文. 重庆: 西南大学.]
- Fu XT, Cao YZ, Dong XT, Chang J, Huo ZJ, Meng RX, 2024. Functional responses of two species of predatory mites (Acari: Phytoseiidae) to eggs and first-instar nymphs of *Bactericera gobica* Logniov (Homoptera: Psyllidae). *Experimental and Applied Acarology*, 93(1): 197–210.
- Fu XT, Zeng KK, Huo ZJ, Chang J, Meng RX, 2025. Demographic and predatory parameters of a thelytokous phytoseiid mite as a biocontrol agent for spider mites. *Pest Management Science*, 81(8): 4540–4547.
- Gan M, Li MH, Hu SQ, 2001. A study on the capture effect of predatory mite *Amblyseius orientalis* to red mite *Panonychus citri*. *Journal of Nanchang University (Natural Science)*, 25(2): 131–133. [甘明, 李明慧, 胡思勤, 2001. 东方钝绥螨对柑桔全爪螨捕食效应的研究. 南昌大学学报(理科版), 25(2): 131–133.]
- Gols R, Schütte C, Stouthamer R, Dicke M, 2007. PCR-based

- identification of the pathogenic bacterium, *Acaricomes phytoseiuli*, in the biological control agent *Phytoseiulus persimilis* (Acari: Phytoseiidae). *Biological Control*, 42(3): 316–325.
- Gong YJ, Chen PY, Wang ZH, Zhu L, Chen JC, Jin GH, Wei SJ, 2017. Effects of temperature on development and oviposition of the predatory mite *Phytoseiulus persimilis*. *Plant Protection*, 43(5): 74–78. [宫亚军, 陈鹏燕, 王泽华, 朱亮, 陈金翠, 金桂华, 魏书军, 2017. 温度对智利小植绥螨发育和繁殖的影响. 植物保护, 43(5): 74–78.]
- Guo JH, Meng RX, Zhang DX, Yin YF, Jia YH, Liu WM, 2016. Intraguild predation and cannibalism in the phytoseiid mites *Euseius utilis* and *Neoseiulus barkeri* (Acari: Phytoseiidae). *Acta Entomologica Sinica*, 59(5): 560–567. [郭建哈, 孟瑞霞, 张东旭, 尹云飞, 贾永红, 刘文明, 2016. 有益真绥螨与巴氏新小绥螨的集团内捕食和同类相残作用. 昆虫学报, 59(5): 560–567.]
- Guo L, Zheng DR, Wu HJ, 2014. Effects of temperature on the predatory efficiency of *Blattisocius dentriticus* to pest mite, *Tyrophagus putrescentiae*. *Journal of Beijing University of Agriculture*, 29(1): 74–76. [郭蕾, 郑大睿, 吴洪基, 2014. 温度对等钳蠊螨捕食腐食酪螨效率的影响. 北京农学院学报, 29(1): 74–76.]
- Guo YJ, Dong HF, 1987. Effects of variable temperature and humidity on the development and survival of *Phytoseiulus persimilis*. *Biological Control*, 3(1): 19–22. [郭玉杰, 董慧芳, 1987. 变温变湿对智利小植绥螨发育和存活的影响. 生物防治通报, 3(1): 19–22.]
- Han GD, Tang SQ, Su J, Chen J, Zhang JP, 2020. Prey preference of the predatory mite *Neoseiulus bicaudus* Wainstein (Phytoseiidae) on *Bemisia tabaci* and *Tetranychus turkestanii*. *Chinese Journal of Biological Control*, 36(3): 347–352. [韩国栋, 唐思琼, 苏杰, 陈静, 张建萍, 2020. 双尾新小绥螨对烟粉虱和土耳其斯坦叶螨的捕食选择性. 中国生物防治学报, 36(3): 347–352.]
- He LM, Li LT, Yu LC, He XZ, Jiao R, Xu CX, Zhang LL, Liu JL, 2019. Optimizing cold storage of the ectoparasitic mite *Pyemotes zhonghuajia* (Acari: Pyemotidae), an efficient biological control agent of stem borers. *Experimental and Applied Acarology*, 78(3): 327–342.
- He YF, Li DY, Li HD, Liang LR, 1993. Capture function of *Amblyseius aizawai* Ehara et Bhandhuflach to *Panonychus citri* Magregor. *Guizhou Agricultural Sciences*, 21(3): 37–40. [何永福, 李德友, 李宏度, 梁来荣, 1993. 间泽钝绥螨对柑桔全爪螨的捕食作用. 贵州农业科学, 21(3): 37–40.]
- He YJ, Jia BH, Lü JL, Wang ED, Xu XN, 2019a. Analyses of the nutritional requirements of *Tetranychus urticae*. *Chinese Journal of Applied Entomology*, 56(4): 678–686. [何永娟, 贾冰红, 吕佳乐, 王恩东, 徐学农, 2019. 二斑叶螨及其寄主植物(芸豆)营养分析. 应用昆虫学报, 56(4): 678–686.]
- He YJ, Lv JL, Wang ED, Xu XN, 2019b. Reproductive performance and transcriptome analyses of *Tetranychus urticae* when feeding on bean leaves and an artificial diet. *Systematic and Applied Acarology*, 24(7): 1272–1283.
- Hou F, Ni ZH, Zou MT, Zhu R, Yi TC, Guo JJ, Jin DC, 2022. Life table parameters and predation ability of *Amblyseius herbicolus* (Acarina: Phytoseiidae) reared continuously on *Oulenzia bakeri* (Acarina: Winterschmidtidae). *Acta Entomologica Sinica*, 65(7): 886–894. [侯飞, 倪召红, 邹梦婷, 朱睿, 乙天慈, 郭建军, 金道超, 2022. 贝氏小奥林螨连续饲养的草栖钝绥螨生命表参数和捕食能力. 昆虫学报, 65(7): 886–894.]
- Hu HM, Li Q, Jiang CX, Wang HJ, Yang QF, 2020. Effects of fluctuating temperature and photoperiod on sex differentiation and reproduction of *Neoseiulus californicus* (Parasitiformes: Phytoseiidae). *Chinese Journal of Biological Control*, 36(2): 294–299. [胡昊旻, 李庆, 蒋春先, 王海建, 杨群芳, 2020. 变温和光周期对加州新小绥螨性别分化及繁殖的影响. 中国生物防治学报, 36(2): 294–299.]
- Huang BT, Li MX, Jiang XH, Zhang B, Huang Y, Xu XN, 2024. Reproductive structures of female *Phytoseiulus persimilis* (Acari: Phytoseiidae) and the development of egg and embryo in the body. *Agriculture*, 14(9): 1647.
- Huang H, Xu XN, Lv JL, Li GT, Wang ED, Gao YL, 2013. Impact of proteins and saccharides on mass production of *Tyrophagus putrescentiae* (Acari: Acaridae) and its predator *Neoseiulus barkeri* (Acari: Phytoseiidae). *Biocontrol Science and Technology*, 23(11): 1231–1244.
- Huang JH, Freed S, Wang LS, Qin WJ, Chen HF, Qin HG, 2014. Effect of temperature on development and reproduction of *Proprioseiopsis asetus* (Acari: Phytoseiidae) fed on asparagus thrips, *Thrips tabaci*. *Experimental and Applied Acarology*, 64(2): 235–244.
- Huang JH, Qin WJ, Luo RH, Huang SJ, Qin HG, Fu ZF, 2012. Influences of temperature on development, survival and reproduction of *Amblyseius barkeri* on asparagus thrips, *Thrips tabaci*. *Chinese Journal of Applied Entomology*, 49(3): 710–714. [黄建华, 秦文婧, 罗任华, 黄水金, 秦厚国, 付志飞, 2012. 温度对取食芦笋蓟马的巴氏钝绥螨生长发育、存活和繁殖的影响. 应用昆虫学报, 49(3): 710–714.]
- Huang MD, Ouyang GC, 2025. Research and application of *Ageratum conyzoides* as ground cover plant against citrus pests. *Journal of Environmental Entomology*, 47(3): 776–783. [黄明度,

- 欧阳革成, 2025. 柑橘-藿香蓍复合种植系统控害作用的研究与应用. *环境昆虫学报*, 47(3): 776–783.]
- Huang MD, 2008. Study on Insect Community Diversity in Complex Planting Systems. Guangzhou: Guangdong Science and Technology Press. 135. [黄明度, 2008. 复合种植系统昆虫群落多样性研究. 广州: 广东科技出版社. 135.]
- Huang WK, Chen JJ, Guo JY, Fu QW, Huang GS, Luo F, 2022. Functional responses and field efficacy of the predatory mite on controlling the bean flower thrips. *China Cucurbits and Vegetables*, 35(3): 92–98. [黄伟康, 陈积杰, 郭静依, 符启位, 黄国宋, 罗丰, 2022. 巴氏钝绥螨对普通大蓟马的功能反应及田间防效. *中国瓜菜*, 35(3): 92–98.]
- Jia BH, 2016. Ultrastructure of the mouthparts of tetranychid mites and a study on the artificial diet of *Tetranychus urticae* Koch (Acari: Tetranychidae). Master dissertation. Hefei: Anhui Agricultural University. [贾冰红, 2016. 叶螨口器显微结构及二斑叶螨人工饲料初探. 硕士学位论文. 合肥: 安徽农业大学.]
- Jia JJ, Chen JY, Zhang FP, Niu LM, Fu YG, 2019a. Function response of *Neoseiulus californicus* feeding on *Eotetranychus sexmaculatus* at different temperatures. *Journal of Environmental Entomology*, 41(4): 857–865. [贾静静, 陈俊谕, 张方平, 牛黎明, 符悦冠, 2019a. 加州新小绥螨在不同温度下对六点始叶螨的捕食效能. *环境昆虫学报*, 41(4): 857–865.]
- Jia JJ, Fu YG, Zhang FP, Liang M, Chen JY, 2019b. Effects of temperature on predatory functional responses of *Neoseiulus californicus* to *Eutetranychus orientalis*. *Chinese Journal of Biological Control*, 35(3): 382–389. [贾静静, 符悦冠, 张方平, 梁敏, 陈俊谕, 2019b. 温度对加州新小绥螨捕食东方真叶螨功能反应的影响. *中国生物防治学报*, 35(3): 382–389.]
- Jia JJ, Fu YG, Zhang FP, Niu LM, Chen JY, 2018. Effects of temperature on predatory functional responses of *Neoseiulus californicus* to *Oligonychus biharens*. *Chinese Journal of Tropical Crops*, 39(10): 2028–2033. [贾静静, 符悦冠, 张方平, 牛黎明, 陈俊谕, 2018. 温度对加州新小绥螨捕食比哈小爪螨功能反应的影响. *热带作物学报*, 39(10): 2028–2033.]
- Jia JJ, Fu YG, Zhang FP, Zhou SH, Nie Y, Chen JY, 2019c. Evaluation of *Euseius nicholsi* as a biological control for three species of spider mites in rubber plantations. *Chinese Journal of Applied Entomology*, 56(4): 718–727. [贾静静, 符悦冠, 张方平, 周世豪, 聂跃, 陈俊谕, 2019c. 尼氏真绥螨对三种橡胶叶螨的控害效能评价. *应用昆虫学报*, 56(4): 718–727.]
- Jiang HH, Li XQ, Yao ZC, Tan YG, Yan GC, 1988. Studies on the bionomics and predation of *Amblyseius eharai* on *Panonychus citri*. *Natural Enemies of Insects*, 10(3): 165–169. [江汉化, 李秀清, 姚正昌, 谭跃庚, 阎光春, 1988. 江原钝绥螨的生物学及其对柑桔全爪螨捕食作用的研究. *昆虫天敌*, 10(3): 165–169.]
- Jiang HL, Wang ED, Lü JL, Wang BM, Xu XN, 2015. Preference of *Neoseiulus californicus* (Acari: Phytoseiidae) and functional responses of *N. californicus* and *Amblyseius pseudolongispinosus* to prey developmental stages of *Tetranychus cinnabarinus*. *Chinese Journal of Biological Control*, 31(1): 8–13, 27. [蒋洪丽, 王恩东, 吕佳乐, 王伯明, 徐学农, 2015. 加州新小绥螨对朱砂叶螨不同螨态的捕食选择性及与拟长毛钝绥螨功能反应比较. *中国生物防治学报*, 31(1): 8–13, 27.]
- Jiang JQ, Zhang Y, Ma L, Niu TT, Dong TT, Sheng RR, Li L, Xu YY, Xi LY, Li AG, 2020. Molecular characterization of *Neoseiulus barkeri* vitellogenin genes and vitellogenin receptor during reproductive diapause. *Insects*, 11(4): 203.
- Jiang XH, Lv JL, Wang ED, Xu XN, 2019. Spermatophore producing process and sperm transfer in *Phytoseiulus persimilis*. *Experimental and Applied Acarology*, 77(1): 11–25.
- Jin MR, Xin TR, Zheng ZH, Zhang C, Huang XY, Li ZZ, Liu YM, Wang J, Zou ZW, Xia B, 2023. Yeast in addition to pollen enhances the reproduction of the predatory mite *Euseius nicholsi* by increasing the target of rapamycin gene expression. *Biological Control*, 177: 105101.
- Jing ZQ, Yang YY, Li XY, Qu YF, Dong HQ, Wu QH, 2001. The relation between the development time of *Amblyseius cucumeris* and the temperature. *Journal of Fudan University (Natural Science Edition)*, 40(5): 577–580. [经佐琴, 杨琰云, 李新义, 屈云芳, 董慧琴, 吴千红, 2001. 黄瓜钝绥螨发育历期与温度的关系. *复旦学报(自然科学版)*, 40(5): 577–580.]
- Kong ZY, Zhang B, Xu XN, Wang ED, 2025. Genetic identification and expression analysis of HSPs genes in *Phytoseiulus persimilis* Athias-Henriot. *Systematic and Applied Acarology*, 30(9): 1672–1680.
- Li GY, Zhang ZQ, 2020. Can supplementary food (pollen) modulate the functional response of a generalist predatory mite (*Neoseiulus cucumeris*) to its prey (*Tetranychus urticae*)? *Biological Control*, 65(2): 165–174.
- Li JM, Wu QH, Yang YY, 2003. Functional response of female adults of *Amblyseius cucumeris* to *Polyphagotarsonemus latus*. *Journal of Fudan University: Natural Science*, 42(4): 593–596. [李佳敏, 吴千红, 杨琰云, 2003. 黄瓜钝绥螨对茶黄螨的功能反应. *复旦学报(自然科学版)*, 42(4): 593–596.]
- Li LT, Jiao R, Yu LC, He XZ, He LM, Xu CX, Zhang LL, Liu JL, 2018. Functional response and prey stage preference of *Neoseiulus barkeri* on *Trasonemus confusus*. *Systematic and Applied Acarology*, 23(11): 2244–2258.

- Li MX, Wang ZH, Wang ED, Zhang B, Lv JL, Xu XN, 2023. Expression and function analyses of sex-lethal gene in *Phytoseiulus persimilis*. *Systematic and Applied Acarology*, 28(8): 1356–1367.
- Li N, Li B, Qu YF, Li JM, Dong HQ, Wu QH, Yang YY, 2002. Influence of temperature on the developmental rates of *Amblyseius cucumeris* with *Tetranychus cinnabarinus* as its prey. *Journal of Fudan University (Natural Science Edition)*, 41(1): 79–82. [李宁, 李斌, 屈云芳, 李佳敏, 董慧琴, 吴千红, 杨琰云, 2002. 温度对以叶螨为食的黄瓜钝绥螨发育速率的影响. 复旦学报(自然科学版), 41(1): 79–82.]
- Li XY, Yang YY, Qu YF, Jing ZQ, Wu QH, 2001. Functional response of *Amblyseius cucumeris* on female adult of *Polyphagot arsonemus* latus and on egg of *Tyrophagus putrescentiae*. *Acta Arachnologica Sinica*, 10(2): 43–47. [李新义, 杨琰云, 屈云芳, 经佐琴, 吴千红, 2001. 黄瓜钝绥螨对茶黄螨雌成螨和腐食酪螨卵的功能反应. 蛛形学报, 10(2): 43–47.]
- Li XY, Zhao WJ, Zheng WW, Zhang HY, 2021. Predation abilities of the *Amblyseius eharai* on different prey species. *Chinese Journal of Biological Control*, 37(3): 443–450. [李晓杨, 赵文娟, 郑薇薇, 张宏宇, 2021. 江原钝绥螨对三种橘园害虫的捕食能力. 中国生物防治学报, 37(3): 443–450.]
- Li YJ, Liu QY, Chang J, Jia YH, Meng RX, 2019. Effects of temperature on a Chinese population of *Amblyseius andersoni* (Acari: Phytoseiidae) fed with *Tetranychus urticae*. *Acarologia*, 59(4): 475–483.
- Li YT, Jiang JYQ, Huang YQ, Wang ZH, Zhang JP, 2015. Effects of temperature on development and reproduction of *Neoseiulus bicaudus* (Phytoseiidae) feeding on *Tetranychus turkestanii* (Tetranychidae). *Systematic and Applied Acarology*, 20(5): 478–490.
- Ling P, Xia B, Li PX, Shu C, Zhong L, Li AH, 2008. Functional response of *Amblyseius barkeri* (Acarina: Phytoseiidae) on *Panonychus citri* (Acari: Tetranychidae). *Acta Arachnologica Sinica*, 17(1): 29–34. [凌鹏, 夏斌, 李朋新, 舒畅, 钟玲, 李爱华, 2008. 巴氏钝绥螨对柑桔全爪螨的捕食效能. 蛛形学报, 17(1): 29–34.]
- Liu BM, Zhang JM, Guo XJ, Zhang F, 2012. Effects of storage temperature, matrix and duration on survival and fecundity of the predatory mite *Phytoseiulus persimilis*. *Plant Protection*, 38(6): 54–58. [刘佰明, 张君明, 郭晓军, 张帆, 2012. 冷藏温度、基质和时间对智利小植绥螨存活和生殖的影响. 植物保护, 38(6): 54–58.]
- Liu H, Zhao ZM, Deng YX, He L, Wang JJ, Wu SY, 2002. Effect of temperature on experimental population dynamics of *Typhlodromus bambusae* Ehara (Acari: Phytoseiidae). *Zoological Research*, 23(4): 356–360. [刘怀, 赵志模, 邓永学, 何林, 王进军, 吴仕源, 2002. 温度对竹盲走螨实验种群数量消长的影响. 动物学研究, 23(4): 356–360.]
- Liu JF, Zhang ZQ, 2017. Development, survival and reproduction of a New Zealand strain of *Amblydromalus limonicus* (Acari: Phytoseiidae) on *Typha orientalis* pollen, *Ephesia kuehniella* eggs, and an artificial diet. *International Journal of Acarology*, 43(2): 153–159.
- Liu JF, Zhang ZQ, Beggs JR, Zou X, 2019. Provisioning predatory mites with entomopathogenic fungi or pollen improves biological control of a greenhouse psyllid pest. *Pest Management Science*, 75(12): 3200–3209.
- Liu JY, Lü JL, Wang ED, Xu XN, Wang SS, 2019. Effects of artificial diets supplemented with different nutrient sources on the biology of *Neoseiulus californicus*. *Chinese Journal of Applied Entomology*, 56(4): 710–717. [刘静月, 吕佳乐, 王恩东, 徐学农, 王森山, 2019. 不同营养源添加的人工饲料对加州新小绥螨的生物学影响. 应用昆虫学报, 56(4): 710–717.]
- Liu MX, Wang M, Nima YZ, Feng XT, Li GY, Yang Y, Li YY, Liu H, 2023. Intraguild prey served as alternative prey for intraguild predators in a reciprocal predator guild between *Neoseiulus barkeri* and *Scolothrips takahashii*. *Insects*, 14(6): 561.
- Liu RD, Zhu R, Guo JJ, Yi TC, Jin DC, 2025. High-quality reference genome of predatory mite *Neoseiulus californicus* McGregor (Acari: Phytoseiidae) provides insights into its biological traits and potential RNAi off-target effects. *Pest Management Science*, 81(3): 1638–1656.
- Liu S, 2017. Comparing gnathosoma structure and intrinsic rate of increase among phytoseiid species with different life styles. Master dissertation. Beijing: Chinese Academy of Agricultural Sciences. [刘珊, 2017. 植绥螨生活类型与颚体形态及内禀增长率的关系. 硕士学位论文. 中国农业科学院.]
- Liu S, Lv JL, Wang ED, Xu XN, 2017. Life-style classification of some Phytoseiidae (Acari: Mesostigmata) species based on gnathosoma morphometric. *Systematic and Applied Acarology*, 22(5): 629–639.
- Lu Q, Lv JL, Wang ED, Xu XN, 2022. Impact of starvation on paternal reproductive investment in *Neoseiulus californicus*. *Experimental and Applied Acarology*, 87(1): 1–18.
- Lu TF, Chen JY, Zhang FP, Ye ZP, Li L, Fu YG, 2021. Effects of prey species and density on cannibalism and intraguild predation of predacious mites *Neoseiulus barkeri* and *Amblyseius largoensis*. *Journal of Environmental Entomology*, 43(1): 214–223. [卢塘飞, 陈俊谕, 张方平, 叶政培, 李磊, 符悦冠,

2021. 不同猎物及密度对巴氏新小绥螨和拉戈钝绥螨同类相残和集团内捕食作用的影响. 环境昆虫学报, 43(1): 214–223.]
- Lv JL, Zhang BH, Jiang XH, Wang ED, Xu XN, 2019. Quantitative impact of mating duration on reproduction and offspring sex ratio of *Phytoseiulus persimilis* (Acari: Phytoseiidae). *Journal of Integrative Agriculture*, 18(4): 884–892.
- Lv JL, Yang K, Wang ED, Xu XN, 2016. Prey diet quality affects predation, oviposition and conversion rate of the predatory mite *Neoseiulus barkeri* (Acari: Phytoseiidae). *Systematic and Applied Acarology*, 21(3): 279–287.
- Kong Z, 2024. Screening and evaluation of heat-resistant strains of *Phytoseiulus persimilis* irradiated by ^{60}Co - γ rays. Master dissertation. Beijing: Chinese Academy of Agricultural Sciences. [^{60}Co - γ 射线辐照智利小植绥螨耐热品系筛选与评价. 硕士学位论文. 北京: 中国农业科学院.]
- Ma M, Fan QH, Zhang ZQ, 2019. Ontogenetic changes in the morphology of *Phytoseius leaki* Schicha, 1977 (Acari: Phytoseiidae). *International Journal of Acarology*, 45(1/2): 56–68.
- Ma M, Fan QH, Zhang ZQ, 2020a. *Neoseiulus kikuyu* sp. nov. (Mesostigmata: Phytoseiidae): Descriptions of all life stages from New Zealand. *Systematic and Applied Acarology*, 25(11): 2098–2114.
- Ma M, Zhang B, Fan QH, Zhang ZQ, 2020b. Ontogenetic changes in the morphology of *Neoseiulus barkeri* (Acari: Phytoseiidae). *Zootaxa*, 4009(1): 5–19.
- Mai XH, Li SX, Xiong JJ, Zheng DS, Huang MD, Situ J, 1984. Relationship between ecological factors and population dynamics of *Amblyseius* spp. with application to control of *Panonychus citri*. *Journal of Plant Protection*, 11(1): 29–34. [麦秀慧, 李树新, 熊锦君, 郑德胜, 黄明度, 司徒金, 1984. 生态因素与钝绥螨种群数量关系及应用于防治桔全爪螨的研究. 植物保护学报, 11(1): 29–34.]
- McMurtry JA, Croft BA, 1997. Life-styles of phytoseiid mites and their roles in biological control. *Annual Review of Entomology*, 42: 291–321.
- McMurtry JA, de Moreas GJ, Sourassou NF, 2013. Revision of the lifestyles of phytoseiid mites (Acari: Phytoseiidae) and implications for biological control strategies. *Systematic and Applied Acarology*, 18(4): 297–320.
- Munawar A, Xu Y, Abou El-Ela AS, Zhang YD, Zhong J, Mao ZY, Chen X, Guo H, Zhang C, Sun YQ, Zhu ZR, Baldwin IT, Zhou WW, 2023. Tissue-specific regulation of volatile emissions moves predators from flowers to attacked leaves. *Current Biology*, 33(11): 2321–2329.
- Niu TD, Nima YZ, Li GY, Yang BW, Chen HQ, Li YY, Liu H, 2023. A spätzle protein involved in the immune response of *Neoseiulus barkeri* (Acari: Phytoseiidae) against *Beauveria bassiana*. *Systematic and Applied Acarology*, 28(3): 556–567.
- Shang SQ, Liu P, Zhang XH, 2016. Predatory functional response of *Neoseiulus barkeri* on newly hatched nymphs of *Frankliniella occidentalis*. *Plant Protection*, 42(3): 141–144. [尚素琴, 刘平, 张新虎, 2016. 不同温度下巴氏新小绥螨对西花蓟马初孵若虫的捕食功能. 植物保护, 42(3): 141–144.]
- Sheng FJ, Wang ED, Xu XN, Wang BM, 2014. Life table of experimental population of *Amblyseius orientalis* feeding on *Carpoglyphus lactis*. *Chinese Journal of Biological Control*, 30(2): 194–198. [盛福敬, 王恩东, 徐学农, 王伯明, 2014. 以甜果螨为食的东方钝绥螨的种群生命表. 中国生物防治学报, 30(2): 194–198.]
- Sheng RR, 2021. Research on regulation mechanism of juvenile hormone on reproduction and diapause in *Neoseiulus barkeri*. Master dissertation. Hefei: Anhui Agricultural University. [盛瑞瑞, 2021. 保幼激素对巴氏新小绥螨生殖和滞育的调控机理研究. 硕士学位论文. 合肥: 安徽农业大学.]
- Song ZW, Nguyen DT, Li DS, De Clercq P, 2019. Continuous rearing of the predatory mite *Neoseiulus californicus* on an artificial diet. *BioControl*, 64(2): 125–137.
- Song ZW, Zheng Y, Zhang BX, Li DS, 2016. Prey consumption and functional response of *Neoseiulus californicus* and *Neoseiulus longispinosus* (Acari: Phytoseiidae) on *Tetranychus urticae* and *Tetranychus kanzawai* (Acari: Tetranychidae). *Systematic and Applied Acarology*, 21(7): 936–946.
- Su YZ, Wei JX, Zhang B, Xu XN, 2023. Comparison of chemosensillar in three phytoseiid mites with different feeding habits. *Systematic and Applied Acarology*, 28(11): 1693–1704.
- Su YZ, Zhang B, Xu XN, 2021. Chemosensory systems in predatory mites: From ecology to genome. *Systematic and Applied Acarology*, 26(5): 852–865.
- Sun WW, Xia LY, Wu Y, 2023. Life histories and functional responses of two predatory mites feeding on the stored-grain pest *Liposcelis bostrychophila* Badonnel (Psocoptera: Liposcelidae). *Insects*, 14(5): 478.
- Sun WN, Sarkar SC, Xu XN, Lei ZR, Wu SY, Meng RX, 2018. The entomopathogenic fungus *Beauveria bassiana* used as granules has no impact on the soil-dwelling predatory mite *Stratiolaelaps scimitus*. *Systematic and Applied Acarology*, 23(11): 2165–2172.
- Sun WW, Cui M, Xia LY, Yu Q, Cao Y, Wu Y, 2020. Age-stage, two-sex life tables of the predatory mite *Cheyletus malaccensis* Oudemans at different temperatures. *Insects*, 11(3): 181.
- Sun YH, Zhi JR, Zhang YB, Yuan CM, 2010. Influences of

- temperature on experimental populations of *Amblyseius fallacis*. *Plant Protection*, 36(6): 50–52, 57. [孙月华, 郅军锐, 张玉波, 袁成明, 2010. 温度对伪钝绥螨实验种群的影响. 植物保护, 36(6): 50–52, 57.]
- Tang SQ, Fang C, Su J, Xu D, Lan BY, Lu YH, Zhang JP, 2021. The effect of cold storage on the predation and fecundity of the predatory mite *Neoseiulus bicaudus* (Wainstein). *Journal of Plant Protection*, 48(5): 1088–1095. [唐思琼, 方晨, 苏杰, 徐娣, 蓝碧云, 陆宴辉, 张建萍, 2021. 冷藏对双尾新小绥螨捕食能力和繁殖力的影响. 植物保护学报, 48(5): 1088–1095.]
- Tian CB, Li GY, Wang M, Chen HQ, Ding YS, Chen G, Li YY, Nima YZ, Liu H, 2023a. Activation of MAPK signaling pathway genes leads to promoted thermotolerance in a high-temperature adapted predatory mite *Neoseiulus barkeri* (Hughes). *Systematic and Applied Acarology*, 28(5): 882–902.
- Tian CB, Li YY, Huang J, Chu WQ, Wang ZY, Liu H, 2020. Comparative transcriptome and proteome analysis of heat acclimation in predatory mite *Neoseiulus barkeri*. *Frontiers in Physiology*, 11: 426.
- Tian CB, Li YY, Wu YX, Chu WQ, Liu H, 2021. Sustaining induced heat shock protein 70 confers biological thermotolerance in a high-temperature adapted predatory mite *Neoseiulus barkeri* (Hughes). *Pest Management Science*, 77(2): 939–948.
- Tian CB, Wang YD, Yang XQ, Zhou JS, Gao YZ, Shi JJ, Jiang JH, 2023b. Functional analysis of two mitogen-activated protein kinases involved in thermal resistance of the predatory mite *Neoseiulus californicus* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, 89(3/4): 363–378.
- Wang BM, Xu XN, Jiang XH, Fan QH, Wang ED, Lyu JL, Luo J, Wu MX, Li GT, Dong J, Qiao Y, Wang WQ, Wu SY, Jiang JQ, Wang BB, 2015. A method for mass rearing of *Carpoglyphus lactis*. China invention patent, ZL 2010 1 0524994.9. 2015-02-11. [王伯明, 徐学农, 姜晓环, 范青海, 王恩东, 吕佳乐, 罗佳, 吴梅香, 李桂亭, 董杰, 乔岩, 王伟青, 吴圣勇, 江俊起, 王蓓蓓, 2015. 一种人工大量饲养甜果螨的方法. 中国发明专利. ZL 2010 1 0524994.9. 2015-02-11.]
- Wang BM, Xu XN, Jiang XH, Wang ED, Hu Y, Sheng FJ, Yang K, 2014. A novel method for mass rearing of *Amblyseius orientalis*. China invention patent. ZL 2011 1 0456703.1. 2014-11-26. [王伯明, 徐学农, 姜晓环, 王恩东, 胡毅, 盛福敬, 杨康, 2014. 一种人工大量饲养东方钝绥螨的新方法. 中国发明专利. ZL 2011 1 0456703.1. 2014-11-26.]
- Wang ED, Li C, Jiang XH, Xu XN, 2012. Effect of gamma ray irradiated male adult on oviposition of female and sex ratio of offspring of *Amblyseius pseudolongispinosus*. *Chinese Journal of Biological Control*, 28(3): 348–352. [王恩东, 李超, 姜晓环, 徐学农, 2012. 伽马射线辐照拟长毛钝绥螨雄螨对雌螨产卵量和后代雌性比的影响. 中国生物防治学报, 28(3): 348–352.]
- Wang L, Cheng MM, Fu YM, Fang YH, Wei ZT, Cheng LY, Lei S, Ding LL, Yu SJ, Cong L, Ran C, 2021. Resistance selection and biological characteristics of *Neoseiulus barkeri* (Acari: Phytoseiidae) to chlorpyrifos. *Acta Entomologica Sinica*, 64(3): 374–383. [王莉, 程明明, 傅云梅, 方云洪, 魏志堂, 成禄艳, 雷双, 丁莉莉, 于士将, 丛林, 冉春, 2021. 巴氏新小绥螨毒死蜱抗性选育及生物学特性. 昆虫学报, 64(3): 374–383.]
- Wang ZH, Cai Q, Yan S, Yang SY, Lu Q, Wang ED, Zhang B, Lv JL, Xu XN, 2022a. Molecular characterization, expression, and function of Vitellogenin genes in *Phytoseiulus persimilis*. *Experimental and Applied Acarology*, 86(3): 343–356.
- Wang ZH, Wang ED, Zhang B, Lv JL, Xu XN, 2022b. Potential roles of two doublesex genes during embryogenesis in *Phytoseiulus persimilis*. *Zoosymposia*, 22: 251.
- Wang ZY, Qin SY, Xiao LF, Liu H, 2014. Effects of temperature on development and reproduction of *Euseius nicholsi* (Ehara & Lee). *Systematic and Applied Acarology*, 19(1): 44–50.
- Wei DW, Zeng T, Pu TS, 1995. Functional and numerical responses of four species of phytoseiid mites. *Southwest China Journal of Agricultural Sciences*, 8(1): 120–123. [韦德卫, 曾涛, 蒲天胜, 1995. 四种植绥螨的功能反应和数值反应. 西南农业学报, 8(1): 120–123.]
- Wu SY, Gao YL, Xu XN, Wang DJ, Li J, Wang HH, Wang ED, Lei ZR, 2015. Feeding on *Beauveria bassiana*-treated *Frankliniella occidentalis* causes negative effects on the predatory mite *Neoseiulus barkeri*. *Scientific Reports*, 5: 12033.
- Wu SY, Guo JF, Xing ZL, Gao YL, Xu XN, Lei ZR, 2018. Comparison of mechanical properties for mite cuticles in understanding passive defense of phytoseiid mite against fungal infection. *Materials and Design*, 140: 241–248.
- Wu SY, He Z, Wang ED, Xu XN, Lei ZR, 2017. Application of *Beauveria bassiana* and *Neoseiulus barkeri* for improved control of *Frankliniella occidentalis* in greenhouse cucumber. *Crop Protection*, 96: 83–87.
- Wu SY, Xie HC, Li MY, Xu XN, Lei ZR, 2016a. Highly virulent *Beauveria bassiana* strains against the two-spotted spider mite, *Tetranychus urticae*, show no pathogenicity against five phytoseiid mite species. *Experimental and Applied Acarology*, 70(4): 421–435.
- Wu SY, Xu XN, Wang ED, 2009. Comparison of the functional response for adults of predatory mites, *Euseius castaneau* and

- Neoseiulus cucumeris* on first instar larvae of *Frankliniella occidentalis*. *Chinese Journal of Biological Control*, 25(4): 295–298. [吴圣勇, 徐学农, 王恩东, 2009. 栗真绥螨和黄瓜新小绥螨对西方花蓟马初孵若虫功能反应的比较. *中国生物防治学报*, 25(4): 295–298.]
- Wu SY, Zhang Y, Xu XN, Lei ZR, 2016b. Insight into the feeding behaviour of predatory mites on *Beauveria bassiana*, an arthropod pathogen. *Scientific Reports*, 6: 24062.
- Wu WN, Fang XD, 2021. Systematic Study of Phytoseiid Mites and Their Role in Pest Management. Guangzhou: Guangdong Science and Technology Press. 38–197. [吴伟南, 方小端, 2021. 植绥螨系统学及其对有害生物的治理. 广州: 广东科技出版社. 38–197]
- Wu WN, Lan WM, 1988. Phytoseiid mites in Chinese citrus orchards and their utilization. *Entomological Knowledge*, 25(6): 341–344. [吴伟南, 蓝文明, 1988. 我国柑橘园植绥螨及其利用问题. *昆虫知识*, 25(6): 341–344.]
- Wu WN, Ou JF, Huang JL, 2009. Fauna Sinica, Invertebrata Vol. 47, Arachnida: Acari: Phytoseiidae. Beijing: Science Press. 41–56. [吴伟南, 欧剑峰, 黄静玲, 2009. 中国动物志, 无脊椎动物第四十七卷 蛛形纲 蜱螨亚纲 植绥螨科. 北京: 科学出版社. 41–56.]
- Wu WN, Ouyang DH, Qian X, Ling XH, Wang XC, Liang XP, 1982. Effects of temperature on *Phytoseiulus persimilis* and its preliminary trials for controlling *Tetranychus piercei*. *Journal of Plant Protection*, 9(4): 279–281. [吴伟南, 欧阳定慧, 钱兴, 凌兴汉, 王小川, 梁小萍, 1982. 温度对智利小植绥螨的影响及其防治皮氏叶螨的初步试验. *植物保护学报*, 9(4): 279–281.]
- Wu WN, Zhang JP, Fang XD, Liu H, Guo MF, 2008. Nutritional types of phytoseiid mites and application in biological control. *Chinese Journal of Biological Control*, 24(1): 85–90. [吴伟南, 张金平, 方小端, 刘慧, 郭明昉, 2008. 植绥螨的营养生态学及其在生物防治上的应用. *中国生物防治*, 24(1): 85–90.]
- Wu YX, Li YY, Chu WQ, Niu TD, Feng XT, Ma RJ, Liu H, 2023. Expression and functional characterization of odorant-binding protein 2 in the predatory mite *Neoseiulus barkeri*. *Insect Science*, 30(5): 1493–1506.
- Xia B, Gong ZQ, Yu LP, Zou ZW, Wu ZZ, Zhu ZM, 2005. The effects of temperatures on development and survivorship of *Cheyletus eruditus*. *Journal of Nanchang University (Natural Science)*, 29(3): 286–289. [夏斌, 龚珍奇, 余丽萍, 邹志文, 吴志忠, 朱志民, 2005. 温度对普通肉食螨生长发育和存活率的影响. *南昌大学学报(理科版)*, 29(3): 286–289.]
- Xia B, Zou ZW, Li PX, Lin P, 2012. Effect of temperature on development and reproduction of *Neoseiulus barkeri* (Acari: Phytoseiidae) fed on *Aleuroglyphus ovatus*. *Experimental and Applied Acarology*, 56(1): 33–41.
- Xie ZQ, Hoffmann AA, Zhang B, Xu XN, 2022. Detection, detrimental effects, and transmission pathways of the pathogenic bacterium *Acaricomes phytoseiuli* in commercial predatory mites. *Microbiology Spectrum*, 10(6): e0265422.
- Xin TR, Gong S, Zou ZW, Xia B, 2013. Effects of temperature on predatory functional responses of *Euseius nicholsi* to *Panonychus citri*. *Journal of Nanchang University (Natural Science Edition)*, 37(5): 480–484, 495. [辛天蓉, 龚舒, 邹志文, 夏斌, 2013. 温度对尼氏真绥螨捕食桔全爪螨功能反应的影响. *南昌大学学报(理科版)*, 37(5): 480–484, 495.]
- Xu XN, Liang LR, 1994. Studies on the behavior and reproduction of *Amblyseius pseudolongispinosus* Xin, Liang et Ke (Acarina: Phytoseiidae). *Journal of Anhui Agricultural University*, 21(1): 81–86. [徐学农, 梁来荣, 1994. 拟长毛钝绥螨交配行为及生殖研究. *安徽农业大学学报*, 21(1): 81–86.]
- Yan H, Wang ED, Wei GS, Xu XN, Hurst MRH, Zhang B, 2025. Microbial dynamics across tri-trophic systems: Insights from plant-herbivore-predator interactions. *FEMS Microbiology Ecology*, 101(7): fiaf065.
- Yan H, Wang ED, Wei GS, Zhang B, Xu XN, 2024a. Both host and diet shape bacterial communities of predatory mites. *Insect Science*, 31(2): 551–561.
- Yan H, Wang ED, Xu XN, Wei GS, Zhang B, 2024b. Dissemination patterns and functional role of a symbiotic bacterium *Stenotrophomonas maltophilia* in *Phytoseiulus persimilis*. *Experimental and Applied Acarology*, 94(1): 11.
- Yan JY, Zhang B, Li GT, Xu XN, 2021. Bacterial communities in predatory mites are associated with species and diet types. *Biological Control*, 66(6): 803–811.
- Yang JY, Lv JL, Liu JY, Xu XN, Wang ED, 2019. Prey preference, reproductive performance, and life table of *Amblyseius tsugawai* (Acari: Phytoseiidae) feeding on *Tetranychus urticae* and *Bemisia tabaci*. *Systematic and Applied Acarology*, 24(3): 404–413.
- Yang JY, Sheng FJ, Song ZW, Lü JL, Xu XN, Li DS, Wang ED, 2018. Functional responses of *Amblyseius orientalis* and *A. tsugawai* to eggs and 1st instars of *Bemisia tabaci*. *Chinese Journal of Biological Control*, 34(2): 214–219. [杨静逸, 盛福敬, 宋子伟, 吕佳乐, 徐学农, 李敦松, 王恩东, 2018. 东方钝绥螨与津川钝绥螨对烟粉虱卵及 1 龄若虫的功能反应比较. *中国生物防治学报*, 34(2): 214–219.]
- Yang K, Lü JL, Wang ED, Xu XN, 2015. Impact of additive yeast in prey diet on body size and functional responses of *Neoseiulus*

- barkeri* (Acari: Phytoseiidae). *Chinese Journal of Biological Control*, 31(1): 28–34. [杨康, 吕佳乐, 王恩东, 徐学农, 2015. 猎物饲料中添加酵母对巴氏新小绥螨个体大小及功能反应的影响. *中国生物防治学报*, 31(1): 28–34.]
- Yao H, Zheng W, Tariq K, Zhang H, 2014. Functional and numerical responses of three species of predatory phytoseiid mites (Acari: Phytoseiidae) to *Thrips flavidulus* (Thysanoptera: Thripidae). *Neotropical Entomology*, 43(5): 437–445.
- Yin JD, Li YH, Li XE, Mo WF, Cong Z, Jing W, Xin TR, Zou ZW, Xia B, 2019. Predation of *Cheyletus malaccensis* (Acari: Cheyletidae) on *Megoura japonica* (Hemiptera: Aphididae) under five different temperatures. *International Journal of Acarology*, 45(3): 176–180.
- Yu JJ, Gao FM, Cao FQ, Hao HH, 2018. Effect of *Vigna unguiculata* pollen on development and reproduction of *Euseius ovalis* (Evans). *Chinese Journal of Tropical Crops*, 39(6): 1172–1175. [于静静, 高芳铭, 曹凤勤, 郝慧华, 2018. 不同温度下豇豆花粉对卵圆真绥螨发育及繁殖的影响. *热带作物学报*, 39(6): 1172–1175.]
- Yu SJ, Wang L, Ding LL, Pan Q, Li SC, Liu L, Cong L, Ran C, 2024. A down-regulated cytochrome P450 in *Neoseiulus barkeri* Hughes (Acari: Phytoseiidae) can dechlorinate and hydroxylate chlorpyrifos without producing chlorpyrifos-oxon. *Journal of Hazardous Materials*, 476: 135163.
- Zhang B, Ma M, Fan QH, 2021. Morphological ontogeny of *Neoseiulus zwoelferi* (Acari: Phytoseiidae). *Zootaxa*, 5086(1): 7–28.
- Zhang B, Zheng WW, Zhao WJ, Xu XN, Liu J, Zhang HY, 2014. Intraguild predation among the predatory mites *Amblyseius eharai*, *Amblyseius cucumeris* and *Amblyseius barkeri*. *Biocontrol Science and Technology*, 24(1): 103–115.
- Zhang N, Smith CL, Yin Z, Yan Y, Xie LX, 2022. Effects of temperature on the adults and progeny of the predaceous mite *Lasioseius japonicus* (Acari: Blattisociidae) fed on the cereal mite *Tyrophagus putrescentiae* (Acari: Acaridae). *Experimental and Applied Acarology*, 86(4): 499–515.
- Zhang NX, Deng X, Chen JF, Cao ZL, Ren HL, Jia XF, 1987. Study on *Metaseiulus occidentalis* for control of spider mites in apple orchards. *Bulletin of Biological Control*, 3(3): 97–101. [张乃鑫, 邓雄, 陈建锋, 曹振良, 任慧玲, 贾秀芬, 1987. 西方盲走螨防治苹果树叶螨的研究. *生物防治通报*, 3(3): 97–101.]
- Zhang NX, Kong J, 1987. Development and reproduction of *pseudoamblyseius* at different temperatures. *Entomological Knowledge*, 24(5): 290–291, 321. [张乃鑫, 孔建, 1987. 伪钝绥螨在不同温度下的发育和繁殖. *昆虫知识*, 24(5): 290–291, 321.]
- Zhang Q, Cheng LX, Wen CX, Chang J, Meng RX, Li HP, Wang Z, Dai GX, 2022. Cross-resistance and population parameters analysis of deltamethrin-resistant strains of *Neoseiulus barkeri* to common agents. *Plant Protection*, 48(3): 126–130, 164. [张倩, 成立新, 温彩霞, 常静, 孟瑞霞, 李海平, 王振, 戴桂香, 2022. 巴氏新小绥螨溴氰菊酯抗性品系对常见药剂的交互抗性及其种群参数分析. *植物保护*, 48(3): 126–130, 164.]
- Zhang SY, Cao XW, Han ZQ, Wu WN, 1992. Studies on the effectiveness of the natural control of *Amblyseius orientalis* against two spider mites of *Panonychus ulmi* and *Tetranychus viennensis* in apple orchards. *Natural Enemies of Insects*, 14(1): 21–24. [张守友, 曹信稳, 韩志强, 吴伟南, 1992. 东方钝绥螨对苹果园两种叶螨自然控制作用研究. *昆虫天敌*, 14(1): 21–24.]
- Zhang XR, Wu SY, Reitz SR, Gao YL, 2021. Simultaneous application of entomopathogenic *Beauveria bassiana* granules and predatory mites *Stratiolaelaps scimitus* for control of western flower thrips, *Frankliniella occidentalis*. *Journal of Pest Science*, 94(1): 119–127.
- Zhang XH, 1993. A preliminary report on predatory process of *Euseius finlandicus*: Functional responses and choosing functions. *Journal of Gansu Agricultural University*, 28(3): 287–289, 300. [张新虎, 1993. 芬兰真绥螨捕食作用研究初报: 功能反应和选择性试验. *甘肃农业大学学报*, 28(3): 287–289, 300.]
- Zhang YN, Sheng FJ, Wang ED, Lv JL, Xu XN, 2023. *Amblyseius orientalis* shows high consumption and reproduction on *Polyphagotarsonemus latus* (Banks) in China. *Experimental and Applied Acarology*, 91(4): 561–569.
- Zhang YX, Chen X, Wang JP, Zhang ZQ, Wei H, Yu HY, Zheng HK, Chen Y, Zhang LS, Lin JZ, Sun L, Liu DY, Tang J, Lei Y, Li XM, Liu M, 2019. Genomic insights into mite phylogeny, fitness, development, and reproduction. *BMC Genomics*, 20(1): 954.
- Zhang ZQ, 1988. Progresses and future prospects of Trombidioidea and Erythraeoidea mites as candidates for biological control of insect pests. *Bulletin of Biological Control*, 4(2): 79–82. [张智强, 1988. 以螨治虫的重要类群——绒螨和赤螨研究进展. *生物防治通报*, 4(2): 79–82.]
- Zhao YL, Li DS, Zhang M, Chen W, Zhang GR, 2016. Effects of temperature on the fertility and the expression of Na⁺/K⁺-ATPase α subunit of the biological control agent, *Neoseiulus cucumeris* (Oudemans). *Chinese Journal of Biological Control*, 32(5): 562–568. [赵云龙, 李敦松, 张敏, 陈威, 张古忍, 2016. 温度对胡瓜新小绥螨生殖力及钠钾泵 α 亚基基因表达的影响. *中国生物防治学报*, 32(5): 562–568.]

- Zhi JR, Guo ZZ, Xiong JW, 1992. Influence of temperature on an experimental population of *Amblyseius nicholsi* (Acari: Phytoseiidae). *Bulletin of Biological Control*, 8(3): 115–117. [鄧军锐, 郭振中, 熊继文, 1992. 温度对尼氏钝绥螨实验种群影响的研究. 生物防治通报, 8(3): 115–117.]
- Zhi JR, Ren SX, 2006. The functional response and numerical response of *Amblyseius cucumeris* (Acari: Phytoseiidae) on *Frankliniella occidentalis* (Thysanoptera: Thripidae). *Journal of South China Agricultural University*, 27(3): 35–38. [鄧军锐, 任顺祥, 2006. 胡瓜钝绥螨对西花蓟马的功能反应和数值反应. 华南农业大学学报, 27(3): 35–38.]
- Zhou AN, Zhang XX, 1989. Experimental studies on acarine predator-prey interactions interference and searching efficiency (Acarina: Phytoseiidae). *Journal of Environmental Entomology*, 11(4): 182–186. [周爱农, 张孝羲, 1989. 拟长毛钝绥螨与砾砂叶螨相互作用的实验研究: 功能反应和捕食过程. 昆虫天敌, 11(4): 182–186.]
- Zhou CA, Zou JJ, Huang SD, 1994. The effects of ageratum interplantation in hilly citrus orchard in Hunan province on citrus mite and insect populations. *Journal of Plant Protection*, 21(1): 57–61. [周程爱, 邹建榭, 黄绍东, 1994. 湖南丘陵桔园间种藿香蓟对桔树螨类和昆虫的影响. 植物保护学报, 21(1): 57–61.]
- Zhou HX, Yan H, Wang ED, Zhang B, Xu XN, 2023. Expression and functional analysis of Niemann-Pick C2 gene in *Phytoseiulus persimilis*. *Experimental and Applied Acarology*, 89(2): 201–213.
- Zhou WQ, Xu CL, Xu XN, Zhang BX, Qin HG, Wang ED, Li DS, Xie H, 2012. The predatory mite *Neoseiulus barkeri* (Acari: Phytoseiidae), a new biocontrol approach for plant-parasitic nematode, and associated development and reproduction. *Chinese Journal of Biological Control*, 28(4): 484–489. [周万琴, 徐春玲, 徐学农, 张宝鑫, 秦厚国, 王恩东, 李敦松, 谢辉, 2012. 巴氏新小绥螨的新特性——捕食植物线虫及其发育繁殖. 中国生物防治学报, 28(4): 484–489.]
- Zhou XY, Wang ED, Xu XN, Zhang B, 2025. Chromosome-level genome assembly of *Phytoseiulus persimilis* Athias-Henriot. *Scientific Data*, 12(1): 293.
- Zhu AD, Wang YS, Fang C, Hu HX, Wang JY, Su J, Li HQ, Zhang JP, 2022. Functional response of predatory mite *Neoseiulus bicaudus* on western flower thrips, *Frankliniella occidentalis* at different temperatures. *Journal of Environmental Entomology*, 44(2): 430–439. [朱安迪, 王映山, 方晨, 胡恒笑, 王嘉阳, 苏杰, 李海强, 张建萍, 2022. 不同温度下双尾新小绥螨对西花蓟马的捕食功能反应. 环境昆虫学报, 44(2): 430–439.]
- Zhu JW, Cui XX, Yang J, Lin XM, Yan Y, Cai DC, Li JH, 2023. Functional response of two soil-dwelling predatory mites, *Macrocheles mammifer* (Berlese) (Acari: Macrochelidae), and *Stratiolaelaps scimitus* (Womersley) (Acari: Laelapidae), on thrips *Megalurothrips usitatus* (Bagnall) (Thysanoptera: Thripidae). *Acarologia*, 63(4): 1039–1047.
- Zhu R, Guo JJ, Yi TC, Hou F, Jin DC, 2023. Potential of a winterschmidtiiid prey mite for the production of the predatory mite *Neoseiulus californicus* (Acari: Phytoseiidae). *Experimental and Applied Acarology*, 91(4): 571–584.
- Zhu R, Yi TC, Liu RD, Jin DC, 2024. RNA interference-mediated functional analysis of vitellogenin and vitellogenin receptor in the predatory mite *Neoseiulus californicus*. *Systematic and Applied Acarology*, 29(3): 388–399.