

诱集植物的研究进展及在紫花苜蓿害虫治理中的应用前景*

乔浪^{1,2**} 李德昊¹ 杨佳乐¹ 李玲¹ 李艳艳¹
张文兵¹ 韩海斌² 谭瑶^{1***}

(1. 内蒙古农业大学草原昆虫研究中心, 呼和浩特 010000; 2. 中国农业科学院草原研究所, 呼和浩特 010000)

摘要 诱集植物作为害虫综合治理的措施之一, 在害虫生态调控中发挥重要作用。诱集植物主要类型包括陷阱植物、天敌诱集植物和害虫忌避植物, 发挥诱杀、吸引或忌避的作用, 从而达到保护主栽作物的目的。紫花苜蓿 *Medicago sativa* 因其优良特性, 种植面积不断扩大, 逐渐发展为牧草领域中的支柱产业, 但目前诱集植物在紫花苜蓿害虫防治中鲜有应用。为此, 本文综述了诱集植物的应用研究进展及当前紫花苜蓿重要害虫及综合防治方法, 并整理了已报道的紫花苜蓿害虫取食嗜好植物、忌避植物及害虫天敌取食嗜好植物, 进一步从中筛选出可作为保护紫花苜蓿的备选诱集植物, 为今后应用诱集植物防控提供了依据。

关键词 紫花苜蓿; 诱集植物; 害虫; 天敌; 综合防治

Advances in research on companion plants and prospects for using trap crops for pest control in alfalfa fields

QIAO Lang^{1,2**} LI De-Hao¹ YANG Jia-Le¹ LI Ling¹ LI Yan-Yan¹
ZHANG Wen-Bing¹ HAN Hai-Bin² TAN Yao^{1***}

(1. Research Center for Grassland Entomology, Inner Mongolia Agricultural University, Hohhot 010000, China;

2. Institute of Grassland Research of Chinese Academy of Agricultural Science, Hohhot 010000, China)

Abstract Companion plants play an important role in ecological pest control and integrated pest management. The main types of companion plants include trap plants, plants that attract the natural enemies of crop pests, and plants that are repellent to crop pests, all of which play a role in protecting crops. Because of its excellent characteristics, alfalfa, *Medicago sativa*, has gradually developed into a pillar of the grass industry and the alfalfa growing area has been continuously expanding. However, companion plants are rarely used for managing alfalfa pests. This paper reviews progress in the use of companion plants for alfalfa, the current important alfalfa pests, and methods for the comprehensive control of these. In addition, the feeding preferences of insect pests, pest-repellent plants and predators of alfalfa, are reviewed to identify candidate attractant plants for the protection of alfalfa crops, thereby providing a foundation for the future use of such plants to protect alfalfa.

Key words *Medicago sativa*; trap crops; pest; natural enemy; comprehensive control

紫花苜蓿 *Medicago sativa* 是多年生优质豆科牧草, 在我国有两千多年的栽培历史(谭瑶等, 2015), 在我国东北、华北及西北地区普遍种植, 成为牧草产业中的支柱产业。紫花苜蓿具有极高

的药用、食用、营养及生态价值, 具备栽种范围广、适应性强、对牲畜适口性好等特点(岳彦红等, 2014)。其发达的根系具有很强的根瘤固氮能力, 可增加土壤有机质, 改善土壤质量(Niu

*资助项目 Supported projects: 国家自然科学基金(32160651); 内蒙古自治区关键技术攻关项目(2021GG0057, 2022YFHH0034); 国家牧草产业技术体系(CARS-34-39)

**第一作者 First author, E-mail: 562926654@qq.com

***通讯作者 Corresponding author, E-mail: 850310.tanhuaf4@163.com

收稿日期 Received: 2024-03-05; 接受日期 Accepted: 2024-09-11

et al., 2020), 在水土保持及荒漠化防治中也发挥重要作用。此外, 紫花苜蓿同时为畜牧、乳制品加工、食品、草地绿化等产业的发展带来了良好的经济效益和生态价值(王斌等, 2022; 张海铨等, 2022; Ruan et al., 2024), 因此, 有“牧草之王”的美誉(Ma et al., 2022)。

虫害是制约苜蓿产业发展的重要因素之一, 严重影响着苜蓿的品质和产量(南志标等, 2022)。苜蓿害虫种类多、食性杂、危害重, 我国目前已报道的苜蓿害虫共计 297 种, 分属于 8 目 48 科(张奔等, 2016), 其中鳞翅目和鞘翅目害虫种类最多, 如草地螟 *Loxostege verticalis* (曾娟等, 2018; 张蕾和江幸福, 2022)、苜蓿夜蛾 *Heliothis virescens* 等(雷蕾等, 2016; 李莉莉等, 2016; Zhao et al., 2016), 而缨翅目、半翅目害虫危害最重(韩凤英等, 2012; 李楠等, 2022; Liu et al., 2022a), 包括常发性害虫: 牛角花齿蓟马 *Odontothrips loti* (Li et al., 2019; 朱猛蒙等, 2019; 赵晓东等, 2022)、豌豆蚜 *Acyrtosiphon pisum* (Huang et al., 2022; Ye et al., 2023)、苜蓿蚜 *Aphis craccivora* (于良斌等, 2021; 张育霞等, 2023)、苜蓿斑蚜 *Therioaphis trifolii* (朱猛蒙等, 2011; Yu et al., 2022)、牧草盲蝽 *Lygus pratensis* (Tan et al., 2018, 2021) 等。苜蓿害虫取食苜蓿的幼嫩组织、吸取汁液, 导致苜蓿枝叶干枯、变形、生长受阻(Kipnyargis et al., 2018), 严重时植株矮化、叶片脱落, 还可传播植株病毒, 显著降低了牧草质量及产量(Song et al., 2020)。

植物多样性在控制害虫种群密度中发挥着重要作用(陆宴辉和梁革梅, 2016; Yang et al., 2022)。多作物混合种植区域相对于单一作物种植区域, 害虫危害更轻, 暴发成灾的几率低(陈学新等, 2014)。植物多样性的增加为植食性害虫提供了更多的替代寄主, 也为害虫天敌创造了适宜的栖境, 增强天敌昆虫防控害虫的持效性(Farooq et al., 2022)。近年来, 随着功能植物概念的提出、对多种作物田中害虫天敌的保育及其对害虫的控制效果(戈峰, 2014; 杨泉峰等, 2020; Yang et al., 2021, 2023), 较好地推动了基

于功能植物的害虫生态调控技术的研究发展, 如陷阱植物对于害虫的吸引力明显高于主栽作物, 通过种植陷阱植物, 吸引害虫取食、产卵, 从而达到减轻虫害、保护主栽作物的目的(梁齐等, 2015); 天敌诱集植物可以吸引天敌昆虫, 使其种群得以繁衍、扩增(卢雪凝等, 2021); 害虫忌避植物产生的挥发物对害虫产生驱避作用, 降低害虫危害(陈学新等, 2014)。作为一种低成本、无污染的绿色防控技术, 种植诱集植物已广泛应用于农业生产中, 典型案例如在麦田周围种植功能植物蛇床草, 有利于天敌瓢虫提前迁入麦田控害(杨泉峰等, 2018), 香根草能有效诱集水稻害虫二化螟 *Chilo suppressalis* 在其上产卵, 但不能使二化螟幼虫完成其发育史(Lu et al., 2017; 郑许松等, 2017)。本文将结合害虫生态调控策略的相关原理和研究进展, 综述紫花苜蓿重要害虫及综合防治方法、诱集植物的应用研究进展以及可作为保护紫花苜蓿的备选诱集植物。旨在介绍目前紫花苜蓿重要害虫的危害现状, 为今后开展紫花苜蓿害虫的生态调控提供参考。

1 诱集植物的应用研究进展

探索绿色病虫害防治技术, 实现害虫生态防治已成为热点研究之一, 诱集植物的开发和应用也显示出广阔的前景。目前, 已有大量研究利用诱集植物在粮食作物和经济作物周边种植以进行生物控害(戈峰, 2020), 为粮食增产、保收和重大害虫治理提供宝贵的实践经验。

1.1 棉花

我国是世界第二大棉花生产国, 种植面积约 $3.3 \times 10^{10} \text{ m}^2$, 年产量在 $6 \times 10^9 \text{ kg}$ 以上(陈常兵, 2022), 是我国重要的经济作物。明坤和闫硕(2020)报道, 2014-2018 年在棉花病虫害造成的总产量损失中, 棉花虫害造成的产量损失在 70% 以上。控制棉田害虫的诱集植物主要分为三类: (1) 陷阱植物, 如在棉田点种玉米可引诱玉米螟 *Ostrinia nubilalis* 取食产卵, 降低其对棉花的为害(吴孔明等, 1989)。(2) 天敌诱集植物, 如彭佳敏等(2023)报道, 棉田周围种植

油菜和小麦对捕食性天敌多异瓢虫 *Hippodamia variegata* 等有显著的诱集效果,促进天敌控制棉蚜 *Aphis gossypii*; 罗延亮等(2019)研究表明,棉田周围的苦豆子与棉花上的天敌种类基本相同,天敌数量多于棉田,可作为保育天敌的功能性杂草控制棉田虫害。(3)害虫忌避植物,如在棉田中种植蓖麻,可有效趋避棉铃虫 *Helicoverpa armigera*,降低棉铃虫的落卵量(雒珺瑜等,2018)。此外,研究表明抗虫转 Bt 棉花的种植对靶标害虫棉铃虫低龄幼虫有着良好的毒杀作用,种植 Bt 棉花不仅使棉铃虫的发生数量逐渐降低,同时降低了棉铃虫对其他非 Bt 寄主作物的为害(陆宴辉等,2018),证实了 Bt 棉可作为控制棉铃虫种群的陷阱植物,保护其他主栽作物(Wu *et al.*, 2008)。

1.2 水稻

水稻是我国重要的粮食作物,种植面积占世界 18.3%,总产量占世界的 28%(邓伟等,2022)。目前,香根草作为诱集植物诱集水稻害虫是一类典型的生物防治范例,利用二化螟和大螟 *Sesamia inferens* 的取食产卵特性,诱集雌成虫在香根草上产卵,经发育后的害虫幼虫在取食含有毒性物质的香根草后,体内的毒酶羧酸酯酶(CarE)和细胞色素 P450 酶(P450 酶)的活性受到明显抑制,最终导致害虫死亡(郑许松等,2017; Lu *et al.*, 2022)。

1.3 小麦

我国是小麦的主要产出国和消费国,小麦种植面积大、害虫种类多(门兴元等,2020)。主要以麦蚜、麦红蜘蛛、吸浆虫等为害最重(门兴元等,2020)。近年来,研究者利用作物间作和推拉策略在小麦害虫的防治中做了大量研究,其中小麦与油菜间作(费晓东等,2011)、小麦与大蒜间作(王万磊等,2008)均对麦长管蚜 *Sitobion avenae* 有显著的趋避作用,并有利于吸引害虫天敌迁入麦田,提高麦田产量和生物量。此外,小麦田周围种植紫花苜蓿,可吸引天敌瓢虫,苜蓿刈割后,可使大量瓢虫迁入麦田控害

(Dong *et al.*, 2012)。

1.4 玉米

玉米是我国三大主粮作物之一,长期以来受草地贪夜蛾 *Spodoptera frugiperda* 的为害。自 2019 年,草地贪夜蛾入侵我国,对农业生产造成重大威胁(何朋阳等,2023)。20 世纪 80 年代开始,国内外学者就开展了利用诱集植物控制草地贪夜蛾的研究,Pitre 等(1983)报道,玉米与黄豆间作,可有效降低草地贪夜蛾对玉米的为害。Guera 等(2020)在玉米田设计推拉系统,以臂形草作为诱集植物,能显著吸引草地贪夜蛾雌成虫在其上产卵。豆科植物、禾本科牧草、木薯、苦菜等作为诱集植物与玉米间作套种,均能对草地贪夜蛾发挥良好的控制作用(Cheruiyot *et al.*, 2021; Nwanze *et al.*, 2021; Scheidegger *et al.*, 2021)。

1.5 蔬菜

烟粉虱 *Bemisia taba* 是严重为害蔬菜作物的害虫之一,能携带病毒 400 余种(胡明鑫等,2023)。近年来,利用烟粉虱对寄主作物的取食偏好性,种植嗜好性更高的诱集植物来保护主栽作物,取得了显著效果(李佳倩,2021)。李秋荣等(2019)报道,反枝苋对主栽作物辣椒上的烟粉虱有显著的诱集作用,能吸引其成虫并产卵。此外,烟粉虱成虫对黄瓜有明显的嗜好性(丁雪玲等,2015),可种植黄瓜与其他蔬菜间作诱集烟粉虱。此外,张海波等(2019)研究表明,在蚕豆田四周种植茼蒿,茼蒿开花呈黄色,可利用蚜虫对茼蒿的嗜好性及趋黄色习性,诱集蚜虫取食和产卵。陈泓淦等(2021)通过测定西花蓟马 *Frankliniella occidentalis* 对 8 种寄主植物蔬菜的选择性和嗅觉行为反应,发现西花蓟马对茄子、甘蓝的选择性最高,对香菜、芹菜选择最弱,表现出忌避性。

1.6 果树、花卉

在棉田周围种植杏树,可减少棉蚜的发生,同时可保护和吸引天敌红蜘蛛(王伟等,2012);

甘蔗-玉米间作能降低甘蔗绵蚜 *Oregma lanigera* 的种群密度,并提高其天敌捕食性瓢虫的种群密度,通过天敌瓢虫能有效控制甘蔗绵蚜为害(荆凡胜等,2017);西花蓟马可被菊科、蔷薇科、百合科等多种花卉和芳香植物吸引(Cao *et al.*, 2018; Avellaneda *et al.*, 2022; Zhang *et al.*, 2022b),对杂草牛膝菊表现出显著的取食和产卵趋性。此外,高杭等(2017)报道了大蒜的挥发物对西花蓟马有显著的忌避作用,可用作驱避植物保护主载作物。

2 紫花苜蓿害虫危害现状及综合防治方法

2.1 紫花苜蓿重要害虫

我国目前已报道的苜蓿害虫共计 297 种,分属于 8 目 48 科(张奔等,2016),8 目中报道较多的有 16 科,共 45 种害虫,蓟马类、盲蝽类和蚜虫类害虫为常发性害虫且造成重大危害,具体如表 1 所示。

表 1 紫花苜蓿主要害虫种类
Table 1 Main pest species of alfalfa

目 Order	科 Family	物种 Species
鳞翅目 Coleoptera	夜蛾科 Noctuidae	苜蓿夜蛾 <i>Heliothis dipsacea</i>
		粘虫 <i>Mythimna separata</i>
		棉铃虫 <i>Helicoverpa armigera</i>
		甜菜夜蛾 <i>Laphygma exigua</i>
		小地老虎 <i>Agrotis ipsilon</i>
		斜纹夜蛾 <i>Spodopteralitura fabricius</i>
	螟蛾科 Pyralidae	草地螟 <i>Loxostege sticticalis</i>
		玉米螟 <i>Laphygma exigua</i>
		苜蓿斑螟 <i>Nephopteryx semirubella</i>
		牛角花齿蓟马 <i>Odontothrips loti</i>
缨翅目 Thysanoptera	蓟马科 Thripidae	花蓟马 <i>Frankliniella intonsa</i>
		烟蓟马 <i>Thrips tabaci</i>
		苜蓿蓟马 <i>Frankliniella occidentalis</i>
		普通大蓟马 <i>Megalurothrips usitatus</i>
		豌豆潜叶蝇 <i>Phytomyza horticola</i>
		苜蓿蚜 <i>Aphis medcaginis</i>
双翅目 Diptera	潜叶蝇 Agromyzidae	豌豆蚜 <i>Acyrtosiphon pisum</i>
	蚜科 Aphididae	豆蚜 <i>Aphis craccivora</i>
		苜蓿无网长管蚜 <i>Acyrtosiphon rondo</i>
		苜蓿斑蚜 <i>Therioaphis trifolii</i>
	斑蚜科 Callaphididae	大青叶蝉 <i>Cicadella viridis</i>
	叶蝉科 Cicadellidae	小绿叶蝉 <i>Empoasca flavescens</i>
半翅目 Hemiptera	盲蝽科 Miridae	牧草盲蝽 <i>Lygus pratensis</i>
		苜蓿盲蝽 <i>Adelphocoris lineolatus</i>
		绿盲蝽 <i>Lygus lucorum</i>
		三点盲蝽 <i>Adelphocoris fasiaticollis</i>
		中黑盲蝽 <i>Adelphocoris suturalis</i>
		亚洲小车蝗 <i>Oedaleus decorusasiaticus</i>
直翅目 Mantodea	斑翅蝗科 Oedipodidae	东亚飞蝗 <i>Locusta migratoria migratorioides</i>
	螻蛄科 Gryllotalpidae	东方螻蛄 <i>Gryllotalpa burmeister</i>

续表 1 (Table 1 continued)

目 Order	科 Family	物种 Species
膜翅目 Hymenoptera	广肩小蜂 Eurytonicae	苜蓿籽蜂 <i>Bruchophagus gibbus</i>
鞘翅目 Coleoptera	芫菁科 Meloidae	苹斑芫菁 <i>Mylabris calida</i>
		绿芫菁 <i>Lytta caraganae</i>
		中华豆芫菁 <i>Epicauta chinensis</i>
	丽金龟科 Rutelidae	黄褐丽金龟 <i>Anomala exoleta</i>
		苹毛丽金龟 <i>Proagopertha lucidula</i>
	象甲科 Curculionidae	苜蓿叶象 <i>Hypera postica</i>
		苜蓿籽象甲 <i>Tychius medicaginis</i>
		普通甜菜象甲 <i>Bothynoderus punctiventris</i>
		条纹根瘤象 <i>Sitona lineellus</i>
	金龟科 Melolonthidae	暗黑鳃金龟 <i>Holotrichia purallela</i>
		黑绒鳃金龟 <i>Maladera orientalis</i>
		华北大黑鳃金龟 <i>Holotrichia diomphalia</i>

2.2 紫花苜蓿害虫的综合防治方法

在苜蓿害虫的综合防治方法中, 农业防治措施以预防为主。种植苜蓿抗虫品种是降低虫害的有效途径, 张晴晴等 (2022) 评价了 22 个苜蓿品种对蓟马和蚜虫的抗性, 筛选出同时对蚜虫和蓟马表现出高抗性的“陇东苜蓿”和“敖汉苜蓿”2 个品种。魏江文等 (2022) 研究表明, 豌豆蚜在取食高抗苜蓿品种“甘农 5 号”后, 体内保护酶和解毒酶活性显著变化, 降低了豌豆蚜的存活率。此外, 中耕除草、清洁田园以及间作套种等措施都能有效控制苜蓿病虫害的发生 (李霜等, 2020; 熊兵, 2022)。在苜蓿种植时应合理规划种植环境, 避免与棉花、果树等对牧草盲蝽和蓟马有强烈取食吸引力的作物邻作或间作; 在苜蓿刈割时, 把握好刈割时期, 提前或及时刈割, 刈割过程中尽量降低留茬高度, 可有效降低下茬苜蓿的虫源基数, 对蓟马和蚜虫类等种群数量大、为害周期长的害虫有良好的防效 (朱猛蒙等, 2006; 党志红等, 2021)。

利用苜蓿害虫的趋避性, 使用物理和机械设备对害虫进行防治, 主要方法有诱虫板、诱虫灯和食物诱集。目前报道的蓝色、白色诱虫板对牛角花齿蓟马和苜蓿蚜虫有较好的防效 (刘阳等, 2019; 李楠等, 2020), 绿色诱虫板对牧草盲蝽具有良好的诱杀效果 (迪丽努尔·艾麦提等, 2018)。作为一种理想的杀虫物理工具, 诱虫灯

诱杀的害虫种类多、数量大。研究表明, 波长范围在 340-680 nm 的太阳能诱虫灯可有效诱捕盲蝽科害虫, 单日诱虫量最高可达 40 头/灯 (潘洪生等, 2017)。此外, 根据牛角花齿蓟马、苜蓿蚜虫和牧草盲蝽取食花粉蜜露的特性 (He and Zhang, 2006; 花蕾等, 2007), 配置一定比例的蜜源-糖醋液能起到良好的引诱效果 (耿林等, 2014; 钟宝珠等, 2020), 目前对蓟马引诱活性物质的研究较为深入, 蓟马食诱剂产品也广泛应用到农业生产中 (蔡晓明等, 2018)。

化学防治苜蓿害虫主要使用的杀虫药剂有拟除虫菊酯类、有机磷类、吡虫啉类和阿维菌素 (陶志杰等, 2005; 侯军和贺春贵, 2006; 马亿, 2021), 但随着化学药剂的大量使用, 害虫抗药性迅速发展。目前, 生产中主要以高效、低毒、低残留的杀虫剂为主。罗兰等 (2017) 研究表明, 20%啉虫脒可溶性液剂和 50%吡蚜酮可湿性粉剂均对苜蓿蚜虫和蓟马有良好的防效。李楠等 (2022) 调查发现, 银川地区的牛角花齿蓟马种群对酰胺类、拟除虫菊酯类杀虫剂都产生了中等水平的抗性, 而多杀菌素和乙基多杀菌素对其有显著的防治效果。Tan 等 (2021) 在我国北方农牧交错带的 7 个苜蓿种植区调查了 5 种常用杀虫剂对牧草盲蝽的抗性水平, 结果显示, 拟除虫菊酯类和新烟碱类杀虫剂表现出中等抗性水平, 个别地区对辛硫磷、灭多威和阿维菌素比较敏感, 杀虫作用显著。

苜蓿害虫的生物防治以天敌控害的效果最为显著 (Iturralde-Garcia *et al.*, 2020), 天敌是调控害虫种群动态的关键因素之一 (李姣等, 2014)。据报道, 苜蓿害虫的天敌资源丰富, 包括 58 种天敌昆虫及 10 种蜘蛛 (张奔等, 2016)。刺吸类害虫天敌种类最多, 主要有捕食性天敌瓢虫、草蛉、捕食蝽、食蚜蝇及寄生性天敌蚜茧蜂等 (朱猛蒙等, 2013; 高宇等, 2017; Zhang *et al.*, 2022a)。高有华和刘长仲 (2006) 报道, 多异瓢虫成虫及 4 龄幼虫均对豌豆蚜有强烈的捕食作用。韩凤英等 (2012) 研究表明, 瓢虫、食蚜蝇及蚜茧蜂是苜蓿蚜虫和蓟马的共同天敌, 且天敌的群落结构和数量与害虫种群数量之间有明显的规律性, 并随环境的变化, 交替控制着害虫。

3 保护主栽作物紫花苜蓿的备选诱集植物

目前, 生产上多以紫花苜蓿为诱集植物, 与棉花 (雒珺瑜等, 2018)、蔬菜 (吴圣勇等, 2019)、瓜果 (Hagler *et al.*, 2020) 等作物通过间作套种等方式进行主栽作物的害虫生态调控, 而鲜有种

植诱集植物防控苜蓿病虫害的研究报道。基于前人研究, 本文综述了能够对苜蓿害虫产生吸引或忌避作用, 并能保护和维持苜蓿害虫天敌的植物。这些植物可作为保护主栽作物紫花苜蓿的潜在诱集植物, 为开展紫花苜蓿害虫生态调控的相关研究提供参考。

3.1 备选的陷阱植物和害虫忌避植物

作用于害虫的诱集植物, 其对害虫发挥的功能主要为吸引和忌避两种方式, 最终实现对害虫的集中治理和降低害虫对主栽作物的为害程度。如表 2 和表 3 所示, 整理了苜蓿优势种害虫苜蓿盲蝽 *Adelphocoris lineolatus*、苜蓿斑蚜和苜蓿蚜等, 以及与其亲缘关系较近、为害方式类似的害虫。这些害虫的取食嗜好植物和忌避植物, 共包括十字花科、茄科等 16 个科中的 30 种植物, 作为潜在的诱集植物选择。

3.2 备选的天敌诱集植物

作用于天敌的诱集植物, 对天敌有较高的取食吸引力, 为天敌提供充足的食料和适合的生长发育环境, 有助于对天敌的保护和增殖, 如表 4

表 2 备选的陷阱植物
Table 2 Alternative conventional trap crops

科 Family	诱集植物 Trap crop	栽种方式 Planting method	靶标害虫 Target pest	参考文献 References
十字花科 Cruciferae	甘蓝	外围种植	蓟马 Thrips	陈泓淦等, 2021
	<i>Brassica oleracea</i>	Peripheral planting	蚜虫 Aphids	
	油菜	间作	蚜虫 Aphids	
茄科 Solanaceae	<i>Brassica napus</i>	Row intercropping		Elliott <i>et al.</i> , 2023
	茄子	外围种植	西花蓟马	
	<i>Solanum melongena</i>	Peripheral planting	<i>Frankliniella occidentalis</i>	
	番茄	外围种植	蚜虫 Aphids	
葫芦科 Cucurbitaceae	<i>Solanum lycopersicum</i>	Peripheral planting		Basit <i>et al.</i> , 2021
	黄瓜	外围种植	蚜虫 Aphids	
	<i>Cucumis sativus</i>	Peripheral planting		
豆科 Leguminosae	四季豆	外围种植	西花蓟马	Wang <i>et al.</i> , 2023
	<i>Phaseolus vulgaris</i>	Peripheral planting	<i>Frankliniella occidentalis</i>	
			普通大蓟马	
	饭豇豆	外围种植	<i>Megalurothrips usitatus</i>	陈培育等, 2010
	<i>Vigna unguiculata</i>	Peripheral planting	中黑盲蝽	
	绿豆	外围种植	<i>Adelphocoris suturalis</i>	
	<i>Vigna radiata</i>	Peripheral planting	绿盲蝽	
	蚕豆	间作	<i>Apolygus lucorum</i>	
	<i>Vicia faba</i>	Row intercropping	豌豆蚜	
	草木樨	外围种植	<i>Acyrtosiphon pisum</i>	
	<i>Melilotus officinalis</i>	Peripheral planting	苜蓿盲蝽	
			<i>Adelphocoris lineolatus</i>	Martin <i>et al.</i> , 2021
				陆宴辉, 2008

续表 2 (Table 2 continued)

科 Family	诱集植物 Trap crop	栽种方式 Planting method	靶标害虫 Tatget pest	参考文献 References
夹竹桃科 Orchidaceae	夹竹桃 <i>Nerium indicum</i>	间作 Row intercropping	西花蓟马 <i>Frankliniella occidentalis</i>	曹宇等, 2015
马鞭草科 Verbenaceae	马鞭草 <i>Verbena officinalis</i>	间作 Row intercropping	蓟马 Thrips	卢欣欣, 2021
菊科 Compositae	野艾蒿 <i>Artemisia lavandulaefolia</i>	外围种植 Peripheral planting	绿盲蝽 <i>Apolygus. lucorum</i> 中黑盲蝽 <i>Adelphocoris suturalis</i>	陆宴辉, 2008
	茼蒿 <i>Chrysanthemum coronarium</i>	外围种植 Peripheral planting	苜蓿蚜 <i>Aphis medcaginis</i>	张海波等, 2019
	向日葵 <i>Helianthus annuus</i>	外围种植 Peripheral planting	棉蚜 <i>Aphis gossypii</i>	雒珺瑜等, 2014a
	锦葵科 Malvaceae	外围种植 Peripheral planting	绿盲蝽 <i>Apolygus lucorum</i>	王凯涛等, 2024
玄参科 Scrophulariaceae	毛地黄 <i>Digitalis purpurea</i>	外围种植 Peripheral planting	绿盲蝽 <i>Apolygus lucorum</i>	张晓明等, 2020
蝶形花科 Papilionaceae	三叶草 <i>Trifolium</i>	间作 Row intercropping	欧洲牧草盲蝽 <i>Lygus olaris</i>	Tillman <i>et al.</i> , 2004
蓼科 Polygonaceae	荞麦 <i>Fagopyrum esculentum</i>	外围种植 Peripheral planting	烟蓟马 <i>Thrips tabaci</i>	Buckland <i>et al.</i> , 2017
藜科 Chenopodiaceae	甜菜 <i>Beta vulgaris</i>	外围种植 Peripheral planting	西花蓟马 <i>Frankliniella occidentalis</i>	Chermenskaya <i>et al.</i> , 2001
大戟科 Euphorbiaceae	蓖麻 <i>Ricinus communis</i>	间作 Row intercropping	棉蓟马 <i>Thrips tabaci</i> 绿盲蝽 <i>Apolygus lucorum</i>	雒珺瑜等, 2018 Xiu <i>et al.</i> , 2019

表 3 备选的害虫忌避植物
Table 3 Alternative repellent plants

科 Family	忌避植物 Repellent crop	栽种方式 Planting method	靶标害虫 Tatget pest	参考文献 References
伞形科 Umbelliferae	香菜 <i>Coriandrum sativum</i>	间作 Row intercropping	蓟马 Thrips	陈泓淦等, 2021
百合科 Liliaceae	芹菜 <i>Apium graveolens</i>	间作 Row intercropping	西花蓟马 <i>Frankliniella occidentalis</i>	Cao <i>et al.</i> , 2014
	大蒜 <i>Allium sativum</i>	外围种植 Peripheral planting	西花蓟马 <i>Frankliniella occidentalis</i> 蚜虫 Aphids	Cao <i>et al.</i> , 2014 孙梅梅等, 2016
唇形科 Lamiaceae	迷迭香 <i>Rosmarinus officinalis</i>	外围种植 Peripheral planting	蓟马 Thrips	Song <i>et al.</i> , 2020
菊科 Compositae	薰衣草 <i>Lavandula angustifolia</i>	外围种植 Peripheral planting	蓟马 Thrips	Koschier <i>et al.</i> , 2017
	马郁兰 <i>Origanum majorana</i>	外围种植 Peripheral planting	烟蓟马 <i>Thrips tabaci</i>	金奕轩等, 2023
	薄荷 <i>Mentha arvensis</i>	间作 Row intercropping	蓟马 Thrips	Malheiros <i>et al.</i> , 2016
	洋葱 <i>Allium cepa</i>	间作 Row intercropping	豌豆蚜 <i>Acyrtosiphon pisum</i>	梁薇等, 2022
	母菊 <i>Matricaria recutital</i>	间作 Row intercropping	长毛草盲蝽 <i>Lygus rugulipennis</i>	Easterbrook and Tooley, 1999

表 4 备选的天敌诱集植物

Table 4 Alternative natural enemies attract plants

科 Family	诱集植物 Trap crop	栽种方式 Planting method	靶标天敌 Target natural enemy	参考文献 References
禾本科 Poaceae	玉米 <i>Zea mays</i>	外围种植 Peripheral planting	草蛉 <i>Chrysopa perla</i> , 龟纹瓢虫 <i>Propylaea japonica</i> , 异色瓢虫 <i>Harmonia axyridis</i>	闫占峰等, 2011
	小麦 <i>Triticum aestivum</i>	间作 Row intercropping	瓢虫 Ladybug, 草蛉 <i>Chrysopa perla</i>	赵秀梅等, 2024
	燕麦 <i>Avena sativa</i>	间作 Row intercropping	瓢虫 Ladybug, 草蛉 <i>Chrysopa perla</i>	马建华等, 2020
	高粱 <i>Sorghum bicolor</i>	外围种植 Peripheral planting	草蛉 <i>Chrysopa perla</i>	刘思竹等, 2014
	绿豆 <i>Vigna radiata</i>	外围种植 Peripheral planting	龟纹瓢虫 <i>Propylaea japonica</i> , 异色瓢虫 <i>Harmonia axyridis</i>	雒珺瑜等, 2014b
豆科 Leguminosae	苦豆子 <i>Sophora alopecuroides</i>	外围种植 Peripheral planting	瓢虫 Ladybug, 草蛉 <i>Chrysopa perla</i> , 食蚜蝇 Aphid-eating flies	罗延亮等, 2019
	骆驼刺 <i>Alhagi sparsifolia</i>	外围种植 Peripheral planting	多异瓢虫 <i>Hippodamia variegata</i> , 方斑瓢虫 <i>Propylaea quatuordecimpunctata</i> , 普通草蛉 <i>Chrysopa carnea</i> , 叶色草蛉 <i>Chrysopa phyllochroma</i>	彭雪凡, 2023
	小冠花 <i>Coronilla varia</i>	外围种植 Peripheral planting	食蚜蝇 Aphid-eating flies	程媛, 2020
菊科 Compositae	向日葵 <i>Helianthus annuus</i>	外围种植 Peripheral planting	龟纹瓢虫 <i>Propylaea japonica</i> , 异色瓢虫 <i>Harmonia axyridis</i>	雒珺瑜等, 2014b
	刺儿菜 <i>Cirsium setosum</i>	外围种植 Peripheral planting	普通草蛉 <i>Chrysopa carnea</i> , 叶色草蛉 <i>Chrysopa phyllochroma</i>	刘阳天等, 2021
	泥胡菜 <i>Hemistepta lyrata</i>	外围种植 Peripheral planting	东亚小花蝽 <i>Orius sauteri</i> , 黑带食蚜蝇 <i>Episyrphus balteata</i>	肖云丽等, 2020
	油菜 <i>Brassica napus</i>	间作 Row intercropping	瓢虫 Ladybug, 黑带食蚜蝇 <i>Episyrphus balteata</i> , 寄生蜂 Parasitoids	迟宝杰等, 2014
十字花科 Cruciferae	芥菜 <i>Brassica juncea</i>	外围种植 Peripheral planting	小花蝽 <i>Orius similis</i>	吴月坤等, 2019
	碱蓬 <i>Suaeda glauca bunge</i>	外围种植 Peripheral planting	多异瓢虫 <i>Hippodamia variegata</i> , 草蛉 <i>Chrysopa perla</i> , 食蚜蝇 Aphid-eating flies	李雪玲等, 2019 谢欣, 2020
藜科 Chenopodiaceae	荆芥 <i>Nepeta cataria</i>	外围种植 Peripheral planting	小花蝽 <i>Orius similis</i>	吴月坤等, 2019
	夏至草 <i>Lagopsis supina</i>	外围种植 Peripheral planting	东亚小花蝽 <i>Orius sauteri</i>	吴长兵等, 2022
大戟科 Euphorbiaceae	蓖麻 <i>Ricinus communis</i>	间作 Row intercropping	草间小黑蛛 <i>Erigonidium graminicolum</i> , 草蛉 <i>Chrysopa perla</i>	雒珺瑜等, 2018 吴月坤, 2018
	甘草 <i>Glycyrrhiza uralensis</i>	外围种植 Peripheral planting	多异瓢虫 <i>Hippodamia variegata</i> , 方斑瓢虫 <i>Propylaea quatuordecimpunctata</i>	姜岩等, 2023

所示, 整理了对苜蓿害虫天敌如瓢虫、草蛉、食蚜蝇、寄生蜂、小花蝽等取食吸引力高的 8 个科 18 种植物, 以作为备选的天敌诱集植物。

4 总结与展望

随着“藏粮于草”、“绿色植保”等理念的提出, 紫花苜蓿作为优良的饲草, 其栽培面积不断增大, 害虫防治工作也更复杂严峻, 亟待更高效、绿色防治措施的实施。利用诱集植物对害虫进行生态调控, 兼顾了防控与生态效益的平衡。本文从保护不同重要作物和防控其重大害虫的角度综述了诱集植物的应用研究进展, 以及综述了目前紫花苜蓿上的重大害虫及苜蓿害虫的综合防治方法, 并归纳整理了有潜力作用于苜蓿害虫的陷阱植物 21 种, 忌避植物 9 种, 作用于害虫天敌的诱集植物 18 种。

虽然目前鲜有在紫花苜蓿上诱集植物的研究和应用报道, 但在棉花、水稻等作物上的大量研究表明了诱集植物具有良好的病虫害防控作用, 对未来利用诱集植物防控紫花苜蓿害虫的研究提供了宝贵的经验。本文在综合当前报道的苜蓿害虫寄主选择、取食嗜好等方面的研究基础之上, 筛选出了不同种类可作用于苜蓿害虫和害虫天敌的诱集植物。本文综述结果表明紫花苜蓿诱集植物具有巨大的开发潜力, 今后重要的研究方向应集中于: (1) 更新和扩大备选诱集植物的类别、数量, 调查备选诱集植物是否会吸引其他重大害虫, 而对紫花苜蓿造成危害, 最终建立保护紫花苜蓿的诱集植物库; (2) 通过试验测定苜蓿害虫对苜蓿及备选诱集植物的取食嗜好, 如利用 Y-型嗅觉仪等, 从现有的备选诱集植物中, 选择最佳的诱集植物; (3) 根据诱集植物发挥的不同作用及所选诱集植物的生长特性、生长周期与紫花苜蓿间生长的契合度, 结合实际生产需求, 确定诱集植物的种植方式、种植布局、种植时间等; (4) 根据不同苜蓿种植区发生害虫的类别和程度, 选择具有针对性的诱集植物。

参考文献 (References)

Avellaneda J, Díaz M, Coy-Barrera E, Rodríguez D, 2022. Incidence

and preference of *Frankliniella occidentalis* (Thysanoptera: Thripidae) to different rose cultivars. *Arthropod-Plant Interactions*, 16(2): 205–214.

Basit A, Farhan M, Abbas M, Wang Y, Zhao DG, Mridha AU, Al-Tawaha ARMS, Bashir MA, Arif M, Ahmed S, Alajmi RA, Metwally DM, El-Khadragy M, 2021. Do microbial protein elicitors PeaT1 obtained from *Alternaria tenuissima* and PeBL1 from *Brevibacillus laterosporus* enhance defense response against tomato aphid (*Myzus persicae*)? *Saudi Journal of Biological Sciences*, 28(6): 3242–3248.

Buckland RK, Alston GD, Reeve RJ, Nischwitz C, Drost D, 2017. Trap crops in onion to reduce onion thrips and iris yellow spot virus. *Southwestern Entomologist*, 42(1): 73–90.

Cai XM, Li ZQ, Pan HS, Lu YH, 2018. Research and application of food-based attractants of herbivorous insect pests. *Chinese Journal of Biological Control*, 34(1): 8–35. [蔡晓明, 李兆群, 潘洪生, 陆宴辉, 2018. 植食性害虫食诱剂的研究与应用. 中国生物防治学报, 34(1): 8–35.]

Cao Y, Liu Y, Wang C, Xiong ZL, Li C, 2015. The selectivity of *Frankliniella occidentalis* for the color and volatiles of four host plants. *Chinese Journal of Applied Entomology*, 52(2): 446–453. [曹宇, 刘燕, 王春, 熊正利, 李灿, 2015. 西花蓟马对花卉寄主颜色和挥发物的选择性. 应用昆虫学报, 52(2): 446–453.]

Cao Y, Zhi JR, Cong CL, Margolies DC, 2014. Olfactory cues used in host selection by *Frankliniella occidentalis* (Thysanoptera: Thripidae) in relation to host suitability. *Journal of Insect Behavior*, 27(1): 41–56.

Cao Y, Zhi JR, Zhang RZ, Li C, Liu Y, Lv ZY, Gao YL, 2018. Different population performances of *Frankliniella occidentalis* and *Thrips hawaiiensis* on flowers of two horticultural plants. *Journal of Pest Science*, 91(1): 79–91.

Chen CB, 2002. Current situation and development countermeasures of cotton production in China's inland cotton region. *China Agricultural Technology Extension*, 38(10): 10–13. [陈常兵, 2022. 我国内地棉区棉花生产现状与发展对策. 中国农技推广, 38(10): 10–13.]

Chen HY, Wang YS, Li L, Yang C, Zhang JP, Chen J, 2021. Selective and olfactory responses of *Frankliniella occidentalis* to different host plants. *Plant Protection*, 47(3): 122–126. [陈泓渝, 王映山, 李伦, 杨陈, 张建萍, 陈静, 2021. 西花蓟马对不同寄主植物的选择及嗅觉行为反应. 植物保护, 47(3): 122–126.]

Chen PY, Feng HQ, Li GP, Guo XR, 2010. Analysis of trapping effect of three leguminous plants on cotton Miridae. *Journal of Henan Agricultural Sciences*, 39(5): 66–68. [陈培育, 封洪强, 李国平, 郭线茹, 2010. 3 种豆科植物对棉田盲蝽蟊的诱集效果研究. 河南农业科学, 39(5): 66–68.]

- Chen XX, Liu YQ, Ren SX, Zhang F, Zhang WQ, Ge F, 2014. Plant-mediated support system for natural enemies of insect pests. *Chinese Journal of Applied Entomology*, 51(1): 1–12. [陈学新, 刘银泉, 任顺祥, 张帆, 张文庆, 戈峰, 2014. 害虫天敌的植物支持系统. 应用昆虫学报, 51(1): 1–12.]
- Cheng Y, 2020. Study on the effect of urban green space insectary plants on attracting natural enemy insects. Master dissertation. Beijing: Beijing Forestry University. [程媛, 2020. 城市绿地蜜粉源植物诱集天敌昆虫效应研究. 硕士学位论文. 北京: 北京林业大学.]
- Chermenskaya TD, Burov VN, Maniar SP, Pow EM, Roditakis N, Selytskaya OG, Shamshev IV, Wadhams LJ, Woodcock CM, 2001. Behavioural responses of western flower thrips, *Frankliniella occidentalis* (Pergande), to volatiles from three aromatic plants. *International Journal of Tropical Insect Science*, 21(1): 67–72.
- Cheruiyot D, Chiriboga Morales X, Chidawanyika F, Bruce TJA, Khan ZR, 2021. Potential roles of selected forage grasses in management of fall armyworm (*Spodoptera frugiperda*) through companion cropping. *Entomologia Experimentalis et Applicata*, 169(10): 966–974.
- Chi BJ, Zhu YF, Vandereycken A, Chen JL, Liu Y, 2014. Demographic and quantitative food web analysis of *Sitobion avenae* and its natural enemies. *Chinese Journal of Applied Entomology*, 51(6): 1496–1503. [迟宝杰, 朱英菲, Vandereycken Axel, 陈巨莲, 刘勇, 2014. 麦长管蚜及其天敌的种群发生和食物网分析. 应用昆虫学报, 51(6): 1496–1503.]
- Dang ZH, An JJ, Liu HS, Zhang T, Gao ZL, Pan WL, Li YF, 2021. Application effect of green control technology of alfalfa bug. *China Plant Protection*, 41(11): 39–41. [党志红, 安静杰, 刘浩升, 张涛, 高占林, 潘文亮, 李耀发, 2021. 苜蓿盲蝽绿色防控技术应用效果. 中国植保导刊, 41(11): 39–41.]
- Deng W, Lü Y, Dong YJ, Xu YR, Yang HT, Zhang JW, Zhang JH, Kui LM, Li XL, 2022. The genetic diversity analysis of rice germplasm resources in yunnan province of China. *Journal of Plant Genetic Resources*, 24(3): 1–13. [邓伟, 吕莹, 董阳均, 徐雨然, 杨华涛, 张锦文, 张建华, 奎丽梅, 李小林, 2022. 云南水稻种质资源的遗传多样性分析. 植物遗传资源学报, 24(3): 1–13.]
- Dilinuer · AIMAITI, Liu DC, Feng HZ, 2018. Attractive effect of differently colored sticky traps on *Lygus pratensis*. *China Cotton*, 45(9): 23–25. [迪丽努尔·艾麦提, 刘端春, 冯宏祖, 2018. 不同颜色粘虫板对牧草盲蝽的诱集作用. 中国棉花, 45(9): 23–25.]
- Ding XL, Zhao JW, Yao FL, Zheng Y, He YX, 2015. Pest management on *Bemisia tabaci* using trap plants. *Fujian Journal of Agricultural Sciences*, 30(5): 504–508. [丁雪玲, 赵建伟, 姚凤奎, 郑宇, 何玉仙, 2015. 利用诱集植物防治烟粉虱的研究. 福建农业学报, 30(5): 504–508.]
- Dong ZK, Gao FJ, Zhang RZ, 2012. Use of ryegrass strips to enhance biological control of aphids by ladybirds in wheat fields. *Insect Science*, 19(4): 529–534.
- Easterbrook MA, Tooley JA, 1999. Assessment of trap plants to regulate numbers of the European tarnished plant bug, *Lygus rugulipennis*, on late-season strawberries. *Entomologia Experimentalis et Applicata*, 92(2): 119–125.
- Elliott NC, Giles KL, Baum KA, Elzay SD, Backoulou GF, 2023. Role of parasitoids and landscape structure in aphid population dynamics in winter canola. *Biological Control*, 186: 105330.
- Farooq MO, Razaq M, Shah FM, 2022. Plant diversity promotes species richness and community stability of arthropods in organic farming. *Arthropod-Plant Interactions*, 16(6): 593–606.
- Fei XD, Li C, Zhang QW, Zhao ZW, 2011. The effects of wheat planted adjacent to rape on natural enemy population dynamics and wheat production. *Plant Protection*, 37(6): 186–190. [费晓东, 李川, 张青文, 赵章武, 2011. 油菜-小麦邻作模式对麦蚜主要天敌种群动态以及小麦生产的影响. 植物保护, 37(6): 186–190.]
- Gao H, Zhi JR, Liu L, 2017. Effect of favorite and non-favorite host on the selectivity of *Frankliniella occidentalis*. *Journal of Biosafety*, 26(4): 285–288. [高杭, 郑军锐, 刘利, 2017. 嗜食植物与非嗜食植物对西花蓟马成虫寄主选择性的影响. 生物安全学报, 26(4): 285–288.]
- Gao Y, Liu YC, Shi SS, Xu W, Hou XJ, 2017. Progress in research and application of phototaxis and chromatics tropism of Thysanoptera pests. *Jiangsu Journal of Agricultural Sciences*, 33(6): 1427–1434. [高宇, 刘延超, 史树森, 徐伟, 侯向洁, 2017. 缨翅目害虫趋光性及趋色性研究应用进展. 江苏农业学报, 33(6): 1427–1434.]
- Gao YH, Liu CZ, 2006. Studies on the predatory function of *Hippodamia (Adonia) variegata* (Goeze) to *Acyrtosiphon pisum* (Harris). *Plant Protection*, 32(6): 51–53. [高有华, 刘长仲, 2006. 多异瓢虫对豆无网长管蚜捕食作用研究. 植物保护, 32(6): 51–53.]
- Ge F, 2020. The ecological regulation and management of pests. *Chinese Journal of Applied Entomology*, 57(1): 10–19. [戈峰, 2020. 论害虫生态调控策略与技术. 应用昆虫学报, 57(1): 10–19.]
- Ge F, Ouyang F, Zhao ZH, 2014. Ecological management of insects based on ecological services at a landscape scale. *Chinese Journal of Applied Entomology*, 51(3): 597–605. [戈峰, 欧阳芳, 赵紫华, 2014. 基于服务功能的昆虫生态调控理论. 应用昆虫学报, 51(3): 597–605.]

- Geng L, Bi YG, Wang ZG, 2014. Study on the seductive effect of nectar sources-sweet and sour solution on alfalfa bug. *Forestry and Ecological Sciences*, 29(3): 307–309, 319. [耿林, 毕拥国, 王志刚, 2014. 蜜源-糖醋液对苜蓿盲蝽的引诱作用研究. 河北林果研究, 29(3): 307–309, 319.]
- Guera OGM, Castrejón-Ayala F, Robledo N, Jiménez-Pérez A, Sánchez-Rivera G, 2020. Plant selection for the establishment of push-pull strategies for *Zea mays-Spodoptera frugiperda* pathosystem in Morelos, Mexico. *Insects*, 11(6): 349.
- Hagler JR, Nieto DJ, Machtley SA, Swezey SL, 2020. Predator demographics and dispersal in alfalfa trap-cropped strawberry. *Entomologia Experimentalis et Applicata*, 168(1): 53–58.
- Han FY, Yang H, Qin X, Wang SM, Yang XL, 2012. Study on the species and dynamics of pest insects and their natural enemies on *Medicago sativa* L. in Jinan. *Chinese Agricultural Science Bulletin*, 28(29): 5–9. [韩凤英, 杨慧, 秦旭, 王绍敏, 杨向黎, 2012. 济南市紫花苜蓿害虫和天敌种类及其发生动态的研究. 中国农学通报, 28(29): 5–9.]
- He CG, Zhang XG, 2006. Field evaluation of lucerne (*Medicago sativa* L.) for resistance to aphids in northern China. *Australian Journal of Agricultural Research*, 57(4): 471–475.
- He PY, Li X, Liu TX, Zhang SZ, 2023. Ontogeny of *cotesia ruficrus*, a parasitoid of *Spodoptera frugiperda*. *Chinese Journal of Biological Control*, 39(6): 1–10. [何朋阳, 李贤, 刘同先, 张世泽, 2023. 草地贪夜蛾寄生蜂螟蛉盘绒茧蜂的个体发育. 中国生物防治学报, 39(6): 1–10.]
- Hou J, He CG, 2006. Analysis on the toxicities of 6 insecticides to the pests occurred in alfalfa. *Shaanxi Journal of Agricultural Sciences*, 52(1): 5–6. [侯军, 贺春贵, 2006. 6种杀虫剂对苜蓿常见害虫的生物活性测定. 陕西农业科学, 52(1): 5–6.]
- Hu MX, Yang ZZ, Li Y, Zhang N, Wang F, Bai YC, Jiao XG, Zhang LX, Liu BM, 2023. Cryptic *Bemisia tabaci* species harboring tomato yellow leaf curl virus and endosymbionts and insecticide resistance monitoring in Tianjin. *Journal of Plant Protection*, 50(1): 101–110. [胡明鑫, 杨泽众, 李妍, 张楠, 王芳, 白义川, 焦晓国, 张李香, 刘佰明, 2023. 天津市烟粉虱隐种鉴定及其携带 TYLCV、内共生菌情况和抗药性监测. 植物保护学报, 50(1): 101–110.]
- Hua L, Tao ZJ, Jia ZK, Liu SJ, 2007. Biological characteristics of *Odontothrips loti*. *Journal of Northwest A & F University (Natural Science Edition)*, 35(9): 110–116, 122. [花蕾, 陶志杰, 贾志宽, 刘世建, 2007. 牛角花齿蓟马 *Odontothrips loti* 的生物学特性. 西北农林科技大学学报(自然科学版), 35(9): 110–116, 122.]
- Huang TY, Zhang RB, Yang LL, Cao S, Francis F, Wang B, Wang GR, 2022. Identification and functional characterization of *ApisOr23* in pea aphid *Acyrtosiphon pisum*. *Journal of Integrative Agriculture*, 21(5): 1414–1423.
- Iturralde-Garcia RD, Riudavets J, Castañé C, 2020. Biological control of *Callosobruchus chinensis* (Coleoptera: Chrysomelidae) in stored chickpeas through the release of natural enemies. *Biological Control*, 149: 104322.
- Jiang Y, Song BM, Chen X, Li HB, Wang DM, Akedan · Wuwaishi, Pan HS, 2023. Regulatory effects of *Glycyrrhiza uralensis* strips on population abundances and biocontrol function of *Hippodamia variegata*. *Cotton Science*, 35(1): 39–50. [姜岩, 宋冰梅, 陈鑫, 李号宾, 王冬梅, 阿克旦·吾外士, 潘洪生, 2023. 甘草带对棉田多异瓢虫种群发生与控害的调控功能. 棉花学报, 35(1): 39–50.]
- Jin YX, Huang XY, Li SH, Zhang YF, Gao ZZ, Huang ZJ, Chen FJ, 2023. Selective behavior of western flower thrips *Frankliniella occidentalis* to 12 plant volatile organic compounds. *Journal of Plant Protection*, 50(3): 676–683. [金奕轩, 黄欣怡, 李思涵, 张宇峰, 高振圳, 黄祖金, 陈法军, 2023. 西花蓟马对12种植物挥发物的选择行为. 植物保护学报, 50(3): 676–683.]
- Jing FS, Chen B, Chang HY, Zhao YP, Li ZY, Zhang LM, 2017. The Effect of corn/sugarcane on *Rhopalosiphum maidis* (Fitch), *Ceratomyza lanigera* (Zehntne) and their main natural enemies. *Journal of Yunnan Agricultural University (Natural Science Edition)*, 32(3): 432–441. [荆凡胜, 陈斌, 常怀艳, 赵远鹏, 李正跃, 张立敏, 2017. 玉米/甘蔗对玉米蚜、甘蔗绵蚜及其天敌昆虫的影响. 云南农业大学学报(自然科学), 32(3): 432–441.]
- Kipnyargis AC, Khamis FM, Kenya EU, Ekesi S, Fiaboe KKM, 2018. Genetic diversity of aphid (Hemiptera: Aphididae) species attacking amaranth and nightshades in different agro-ecological zones of Kenya and Tanzania. *African Entomology*, 26(2): 407–421.
- Koschier EH, Nielsen MC, Spangl B, Davidson MM, Teulon DAJ, 2017. The effect of background plant odours on the behavioural responses of *Frankliniella occidentalis* to attractive or repellent compounds in a Y-tube olfactometer. *Entomologia Experimentalis et Applicata*, 163(2): 160–169.
- Lei L, Zhao KJ, Gao YL, Li L, Fan D, 2016. cDNA cloning, expression and characterization of glucose oxidase from *Heliothis virescens*. *Chinese Journal of Applied Entomology*, 53(4): 696–705. [雷蕾, 赵奎军, 高艳玲, 李莉莉, 樊东, 2016. 苜蓿夜蛾葡萄糖氧化酶 cDNA 的克隆、表达及特性研究. 应用昆虫学报, 53(4): 696–705.]
- Li JQ, 2014. Management of the whitefly *Bemisia tabaci* with physical control methods and plant-mediated support system.

- Master dissertation. Hangzhou: Zhejiang University. [李佳倩, 2014. 物理防治和植物支持系统用于烟粉虱防治的研究. 硕士学位论文. 杭州: 浙江大学.]
- Li J, Jin CZ, Long DB, Ouyang F, Ge F, 2014. Non-lethal effects of a natural enemy on herbivore insect population. *Chinese Journal of Applied Entomology*, 51(4): 863–870. [李姣, 金晨钟, 龙大彬, 欧阳芳, 戈峰, 2014. 天敌昆虫对害虫的非直接致死效应. 应用昆虫学报, 51(4): 863–870.]
- Li LL, Zhou XQ, Zhao KJ, Lei L, Fan D, 2016. cDNA cloning and prokaryotic expression of a serine protease from *Heliothis virescens*. *Chinese Journal of Applied Entomology*, 53(4): 706–715. [李莉莉, 周晓群, 赵奎军, 雷蕾, 樊东, 2016. 苜蓿夜蛾丝氨酸蛋白酶基因 cDNA 序列的克隆与原核表达研究. 应用昆虫学报, 53(4): 706–715.]
- Li N, Ma W, Hong B, Wang XP, 2022. Insecticide resistance monitoring of the field populations of thrips on alfalfa in Yinchuan area. *Agrochemicals*, 61(9): 687–692. [李楠, 马雯, 洪波, 王新谱, 2022. 银川地区 4 种苜蓿蓟马田间种群对 10 种杀虫剂的抗药性测定. 农药, 61(9): 687–692.]
- Li N, Ma XX, Wang XP, 2020. Monitoring and trapping effects of yellow and blue sticky traps on the population dynamics of thrips on an alfalfa community. *Pratacultural Science*, 37(10): 2115–2124. [李楠, 马晓霞, 王新谱, 2020. 黄色和蓝色诱虫板对苜蓿蓟马群落发生动态的监测及诱集效果. 草业科学, 37(10): 2115–2124.]
- Li N, Song XM, Wang XP, 2019. The complete mitochondrial genome of *Odontothrips loti* (Haliday, 1852) (Thysanoptera: Thripidae). *Mitochondrial DNA Part B*, 5(1): 7–8.
- Li QR, Li FG, Lai YP, Hou L, Xian WR, Chen LS, 2019. Attractive effect of *Amaranthus retroflexus* on *Bemisia tabaci* in protected chili. *Acta Agriculturae Boreo-occidentalis Sinica*, 28(3): 481–488. [李秋荣, 李富刚, 来有鹏, 侯璐, 咸文荣, 陈来生, 2019. 反枝苋对设施辣椒烟粉虱的诱集作用. 西北农业学报, 28(3): 481–488.]
- Li S, Du GL, Yin XF, Liu XH, Jiang XL, Li YZ, Li XY, Tu XB, Zhang ZH, 2020. Research advance in forage diseases, insect pests and rodents in China. *Chinese Journal of Biological Control*, 36(1): 9–16. [李霜, 杜桂林, 尹晓飞, 刘晓辉, 蒋细良, 李彦忠, 李新一, 涂雄兵, 张泽华, 2020. 我国饲草重大病虫鼠害研究进展. 中国生物防治学报, 36(1): 9–16.]
- Li XL, Luo YL, Li H, Xie X, Ma RH, Liu YJ, Wang PL, Lu YH, 2019. Regulation and control effects of *Suaeda* strips on the population occurrence of *Hippomidia variegata* in cotton fields. *Xinjiang Agricultural Sciences*, 56(1): 13–22. [李雪玲, 罗延亮, 李辉, 谢欣, 马若涵, 刘永建, 王佩玲, 陆宴辉, 2019. 田埂碱蓬带对棉田多异瓢虫种群发生的调控作用. 新疆农业科学, 56(1): 13–22.]
- Li ZY, Han Y, Tang LD, Wu JH, Shaukat A, 2021. Behavioral responses of *Megalurothrips usitatus* (Thysanoptera: Thripidae) to host plant and volatile compounds. *Journal of Environmental Entomology*, 43(6): 1566–1580. [李钊阳, 韩云, 唐良德, 吴建辉, Shaukat A, 2021. 普通大蓟马对寄主植物及其挥发物的行为反应. 环境昆虫学报, 43(6): 1566–1580.]
- Liang Q, Lu YH, He XC, Zheng XS, Xu HX, Yang YJ, Tian JC, Lü ZX, 2015. Mini review of the significance of trap crop in insect pest management. *Journal of Biosafety*, 24(3): 184–193. [梁齐, 鲁艳辉, 何晓婵, 郑许松, 徐红星, 杨亚军, 田俊策, 吕仲贤, 2015. 诱集植物在害虫治理中的最新研究进展. 生物安全学报, 24(3): 184–193.]
- Liang W, Ma YH, Chen LH, Wei HY, 2022. Research progress in the influence of host plants on the selection behaviors of herbivorous insects. *Biological Disaster Science*, 45(3): 299–304. [梁薇, 麻亚辉, 陈丽慧, 魏洪义, 2022. 寄主植物对植食性昆虫选择行为影响的研究进展. 生物灾害科学, 45(3): 299–304.]
- Liu QQ, He J, Song F, Tian L, Cai WZ, Li H, 2022a. Positive correlation of the gene rearrangements and evolutionary rates in the mitochondrial genomes of *Thrips* (Insecta: Thysanoptera). *Insects*, 13(7): 585.
- Liu SZ, Shao TY, Liu XL, 2014. Community structure of predators of the melanaphis sacchari in sorghum field of harbin. *Journal of Beihua University (Natural Science Edition)*, 15(3): 409–411. [刘思竹, 邵天玉, 刘兴龙, 2014. 哈尔滨高粱田高粱蚜捕食性天敌昆虫群落结构研究. 北华大学学报(自然科学版), 15(3): 409–411.]
- Liu Y, Jiang H, Yuan ZL, Luo L, 2019. Attractive effects of sticky boards on *Odonothrips loti* in alfalfa field. *Shandong Agricultural Sciences*, 51(7): 83–86. [刘阳, 姜洪, 袁忠林, 罗兰, 2019. 粘虫板对苜蓿田牛角花齿蓟马的诱集效果. 山东农业科学, 51(7): 83–86.]
- Liu YJ, Wang X, Luo SX, Ma LS, Zhang WW, Xuan SX, Wang YH, Zhao JJ, Shen SX, Ma W, Gu AX, Chen XP, 2022b. Metabolomic and transcriptomic analyses identify quinic acid protecting eggplant from damage caused by western flower thrips. *Pest Management Science*, 78(12): 5113–5123.
- Liu YT, Liu B, Li H, Liu JM, Wang PL, Lu YH, 2021. Lacewing density and dynamics on different weeds in cotton-growing region of northern Xinjiang. *Chinese Journal of Biological Control*, 37(4): 671–678. [刘阳天, 刘冰, 李辉, 刘佳美, 王佩玲, 陆宴辉, 2021. 北疆棉区不同杂草上草蛉发生密度及季节消长. 中国生物防治学报, 37(4): 671–678.]

- Lu XN, Zhang JE, Xiang HM, Wang JX, Lan N, Qin Z, 2021. Review of research and application of trap crops in agriculture. *Ecological Science*, 40(2): 196–203. [卢雪凝, 章家恩, 向慧敏, 王家新, 蓝妮, 秦钟, 2021. 诱集植物在农业中的应用研究进展与展望. *生态科学*, 40(2): 196–203.]
- Lu YH, 2008. Studies on ecological adaptability of the mirids. Doctor dissertation. Beijing: Chinese Academy of Agricultural Sciences. [陆宴辉, 2008. 盲蝽蟥生态适应性研究. 博士学位论文. 北京: 中国农业科学院.]
- Lu YH, Bai Q, Li Q, Zheng XS, Tian JC, Guo JW, Xu HX, Lu ZX, 2022. Two P450 genes, CYP6SN3 and CYP306A1, involved in the growth and development of *Chilo suppressalis* and the lethal effect caused by vetiver grass. *International Journal of Biological Macromolecules*, 223(Pt A): 860–869.
- Lu YH, Jiang YY, Liu J, Zeng J, Yang XM, Wu KM, 2018. Adjustment of cropping structure increases the risk of cotton bollworm outbreaks in China. *Chinese Journal of Applied Entomology*, 55(1): 19–24. [陆宴辉, 姜玉英, 刘杰, 曾娟, 杨现明, 吴孔明, 2018. 种植业结构调整增加棉铃虫的灾变风险. *应用昆虫学报*, 55(1): 19–24.]
- Lu YH, Liang GM, 2016. Research advance on the succession of insect pest complex in Bt crop ecosystem. *Plant Protection*, 42(1): 7–11. [陆宴辉, 梁革梅, 2016. Bt 作物系统害虫发生演替研究进展. *植物保护*, 42(1): 7–11.]
- Lu YH, Zheng XS, Lu ZX, 2017 Application of vetiver grass *Vetiveria zizanioides*: Poaceae (L.) as a trap plant for rice stem borer *Chilo suppressalis*: Crambidae (Walker) in the paddy fields. *Journal of Integrative Agriculture*, 18(4): 797–804.
- Lu XX, 2021. Effects of aggregation pheromone and plant volatiles on the behavior of major vegetable thrips. Master dissertation. Nanjing: Nanjing Agricultural University. [卢欣欣, 2021. 聚集信息素及植物挥发物对蔬菜主要蓟马的行为调控作用. 硕士学位论文. 南京: 南京农业大学.]
- Luo JY, Cui JJ, Wang CY, 2014a. Effects of different ecological regulation on cotton aphids poopulation dynamics. *China Cotton*, 41(1): 17–19. [雒珺瑜, 崔金杰, 王春义, 2014a. 不同生态调控方式对棉田棉蚜种群消长动态的影响. *中国棉花*, 41(1): 17–19.]
- Luo JY, Zhang S, Wang CY, Lü LM, Li CH, Cui JJ, 2014b. Ecological effects of different trap crop to sucking pests and natural enemies in cotton fields. *China Cotton*, 41(8): 14–16. [雒珺瑜, 张帅, 王春义, 吕丽敏, 李春花, 崔金杰, 2014. 不同诱集作物对棉田刺吸性害虫及其天敌的生态作用比较. *中国棉花*, 41(8): 14–16.]
- Luo JY, Zhang S, Zhu XZ, Ji JC, Zhang KX, Wang CY, Zhang LJ, Wang L, Li CH, Cui JJ, 2018. Effect of trap castor on cotton arthropod animal communities and biodiversity. *China Cotton*, 45(8): 9–11, 19. [雒珺瑜, 张帅, 朱香镇, 姬继超, 张开心, 王春义, 张利娟, 王丽, 李春花, 崔金杰, 2018. 蓖麻诱集带对棉田节肢动物群落及生物多样性的影响. *中国棉花*, 45(8): 9–11, 19.]
- Luo L, Yang GF, Liu ZL, Sun J, Yuan ZL, 2017. Control efficacy of acetamiprid and pymetrozine on alfalfa aphides and thrips and the residues in alfalfa. *Chinese Journal of Grassland*, 39(6): 21–25. [罗兰, 杨国锋, 刘兆良, 孙娟, 袁忠林, 2017. 啉虫脒和吡蚜酮对苜蓿蚜虫和蓟马的防效及残留. *中国草地学报*, 39(6): 21–25.]
- Luo YL, Li XL, Li H, Xie X, Liu YJ, Wang PL, Lu YH, 2019. Effects of *Sophora Strips* on the population occurrence of predators in cotton fields. *Xinjiang Agricultural Sciences*, 56(1): 74–83. [罗延亮, 李雪玲, 李辉, 谢欣, 刘永建, 王佩玲, 陆宴辉. 苦豆子条带对棉田捕食性天敌发生的影响. *新疆农业科学*, 56(1): 74–83.]
- Ma JX, Huangfu WK, Yang X, Xu JY, Zhang Y, Wang ZC, Zhu XY, Wang CZ, Shi YH, Cui YL, 2022. “King of the forage”-Alfalfa supplementation improves growth, reproductive performance, health condition and meat quality of pigs. *Frontiers in Veterinary Science*, 2022(9): 1025942.
- Ma Y, 2021. Resistance of *Lygus pratensis* to lambda-cyhalothrin and its physiological, biochemical and molecular mechanisms. Master dissertation. Hohhot: Inner Mongolia Agricultural University. [马亿, 2021. 牧草盲蝽对三氟氯氰菊酯的抗药性及生理生化与分子机制. 硕士学位论文. 呼和浩特: 内蒙古农业大学]
- Ma JH, Wang Y, Yan Y, Chen CJ, 2020. Varieties, laws and hazards of main pest of oats in Ningxia. *Journal of Ningxia Agriculture and Forestry Science and Technology*, 61(12): 46–47, 59. [马建华, 王颖, 闫雅, 陈彩锦, 2020. 宁夏燕麦主要虫害发生种类、规律及危害研究. *宁夏农林科技*, 61(12): 46–47, 59.]
- Malheiros DF, Maciel PO, Videira MN, Tavares-Dias M, 2016. Toxicity of the essential oil of *Mentha piperita* in *Arapaima gigas* (Pirarucu) and antiparasitic effects on *Dawestrema* spp. (Monogenea). *Aquaculture*, 455: 81–86.
- Martin MJ, Hu ZQ, Lu ZQ, 2021. Effects of host plants on the growth, reproduction, and defense in pea aphids, *Acyrtosiphon pisum*. *Current Chinese Science*, 1(6): 586–594.
- Men XY, Dong ZK, Li LL, Yang QF, Zhang QQ, Ouyang F, Lu ZB, Li C, Yu Y, Zhuang QY, 2020. Advances in the integrated management of wheat pests based on ecological regulation. *Chinese Journal of Applied Entomology*, 57(1): 59–69. [门兴元,

- 董兆克, 李丽莉, 杨泉峰, 张晴晴, 欧阳芳, 卢增斌, 李超, 于毅, 庄乾营, 2020. 基于生态调控的小麦害虫综合治理研究进展. 应用昆虫学报, 57(1): 59–69.]
- Ming K, Yan S, 2020. Analysis of the occurrence and control of cotton main diseases and pests in China in recent years. *Cotton Sciences*, 42(3): 13–19, 26. [明坤, 闫硕, 2020. 近几年我国棉花主要病虫害发生及防控情况分析. 棉花科学, 42(3): 13–19, 26.]
- Nan ZB, Wang YR, He JS, Hu XW, Liu ZP, Li CJ, Nie B, Xia C, 2022. Achievements, challenges and prospects of herbage seeds industry in China. *Acta Prataculturae Sinica*, 31(6): 1–10. [南志标, 王彦荣, 贺金生, 胡小文, 刘志鹏, 李春杰, 聂斌, 夏超, 2022. 我国草种业的成就、挑战与展望. 草业学报, 31(6): 1–10.]
- Niu YN, Luo ZZ, Cai LQ, Coulter JA, Zhang YQ, Berti M, 2020. Continuous monoculture of alfalfa and annual crops influence soil organic matter and microbial communities in the rainfed Loess Plateau of China. *Agronomy*, 10(7): 1054.
- Nwanze JAC, Bob-Manuel RB, Zakka U, Kingsley-Umana EB, 2021. Population dynamics of fall army worm [*Spodoptera frugiperda*] J.E. Smith] (Lepidoptera: Nuctuidae) in maize-cassava intercrop using pheromone traps in Niger Delta Region. *Bulletin of the National Research Centre*, 45(1): 44.
- Pan HS, Li GP, Li YF, Lu YH, 2017. The effect of solar energy insect killing lamp on the adult insect of blind bug. *China Plant Protection*, 37(12): 60–62. [潘洪生, 李国平, 李耀发, 陆宴辉, 2017. 太阳能杀虫灯对盲蝽成虫的诱杀效果. 中国植保导刊, 37(12): 60–62.]
- Peng JM, Patima Wumuerhan, Guo XH, Kuerbannisaguli Aobulikasimu, Yang SP, Li TF, Wang XC, Zhu LH, Ma DY, 2023. Effects of trap crops in cotton field on the population dynamics of *Aphis gossypii* and predatory natural enemies. *Chinese Journal of Biological Control*, 39(5): 1–18. [彭佳敏, 帕提玛·乌木尔汗, 郭小虎, 库尔班妮萨古丽·奥布力喀斯木, 杨世平, 李泰峰, 王新翠, 朱丽华, 马德英, 2023. 棉田诱集植物对棉蚜及捕食性天敌种群动态的影响. 中国生物防治学报, 39(5): 1–18.]
- Peng XF, 2023. Effects of different functional plants on cotton aphids and their predatory natural enemy. Master dissertation. Shihezi: Shihezi University. [彭雪凡, 2023. 不同功能植物对棉花蚜虫及其捕食性天敌的影响. 硕士学位论文. 石河子: 石河子大学.]
- Pitre HN, Mulrooney JE, Hogg DB, 1983. Fall armyworm (Lepidoptera: Noctuidae) oviposition: Crop preferences and egg distribution on plants. *Journal of Economic Entomology*, 76(3): 463–466.
- Ruan Q, Bai XM, Wang YZ, Zhang XF, Wang BQ, Zhao Y, Zhu XL, Wei XH, 2024. Regulation of endogenous hormone and miRNA in leaves of alfalfa (*Medicago sativa* L.) seedlings under drought stress by endogenous nitric oxide. *BMC Genomics*, 25(1): 229.
- Scheidegger L, Niassy S, Midega C, Chiriboga X, Delabays N, Lefort F, Zürcher R, Hailu G, Khan Z, Subramanian S, 2021. The role of *Desmodium intortum*, *Brachiaria* sp. and *Phaseolus vulgaris* in the management of fall armyworm *Spodoptera frugiperda* (J. E. Smith) in maize cropping systems in Africa. *Pest Management Science*, 77(5): 2350–2357.
- Song LM, Wang XM, Liu YQ, Sun YP, Ban LP, 2020. Characterization of antennal sensilla and immunolocalization of odorant-binding proteins on spotted alfalfa aphid, *Therioaphis trifolii* (Monell). *Frontiers in Physiology*, 11: 606575.
- Sun MM, Zhen JH, Yao HY, Chai WG, Chen RX, 2016. Repellent effect of 7 non-host plants on main cabbage insect pests. *Acta Agriculturae Zhejiangensis*, 28(8): 1374–1380. [孙梅梅, 湛江华, 姚红燕, 柴伟纲, 陈若霞, 2016. 七种非寄主植物对甘蓝主要害虫的田间驱避作用. 浙江农业学报, 28(8): 1374–1380.]
- Tan Y, Jia B, Chi YM, Han HB, Zhou XR, Pang BP, 2018. The complete mitochondrial genome of the plant bug *Lygus pratensis* Linnaeus (Hemiptera: Miridae). *Journal of Insect Science*, 18(2): 41.
- Tan Y, Jia B, Foster SP, Homem RA, Williamson MS, Han HB, Shan YM, Pang BP, 2021. Sublethal and transgenerational effects of lambda-cyhalothrin on the mirid bugs *Lygus pratensis* Linnaeus and *Polymerus cognatus* Fieber. *Crop Protection*, 139: 105354.
- Tan Y, Wang CY, Meng C, Shi L, Pang BP, 2015. Community composition and diversity of Hemiptera insects on alfalfa in Inner Mongolia. *Journal of Inner Mongolia Agricultural University (Natural Science Edition)*, 36(6): 24–28. [谭瑶, 王春媛, 孟超, 史丽, 庞保平, 2015. 内蒙古地区紫花苜蓿半翅目昆虫群落结构与多样性. 内蒙古农业大学学报(自然科学版), 36(6): 24–28.]
- Tao ZJ, Hua L, Jia ZK, 2005. The population dynamics of thrips on alfalfa and the controlling effects of insecticides. *Agricultural Research in the Arid Areas*, 23(4): 212–214, 218. [陶志杰, 花蕾, 贾志宽, 2005. 苜蓿蓟马的发生规律和药剂防治试验. 干旱地区农业研究, 23(4): 212–214, 218.]
- Tillman G, Schomberg H, Phatak S, Mullinix B, Lachnicht S, Timper P, Olson D, 2004. Influence of cover crops on insect pests and predators in conservation tillage cotton. *Journal of Economic Entomology*, 97(4): 1217–1232.
- Wang B, Li MY, Wang XP, Dong X, Pang JB, Lan J, 2022.

- Combined ploughing and tilling to improve degraded alfalfa (*Medicago sativa*) stands in a semi-arid region. *Acta Prataculturae Sinica*, 31(1): 107–117. [王斌, 李满有, 王欣盼, 董秀, 庞军宝, 兰剑, 2022. 深松浅旋对半干旱区退化紫花苜蓿人工草地改良效果研究. 草业学报, 31(1): 107–117.]
- Wang KT, Yang L, Pan YF, Lu YH, 2024. Seasonal host transfer patterns of *Apolygus lucorum* in southern Xinjiang agroecosystem. *Plant Protection*, 50(2): 278–286. [王凯涛, 杨龙, 潘云飞, 陆宴辉, 2024. 新疆南疆绿盲蝽季节性寄主转移规律. 植物保护, 50(2): 278–286.]
- Wang W, Yao J, Zhang Y, Liu HY, 2012. Effects of apricot trees on insect pests and their natural enemies in nearby cotton fields in southern Xinjiang. *Chinese Journal of Applied Entomology*, 49(4): 951–956. [王伟, 姚举, 张瑜, 刘海洋, 2012. 新疆南部棉区杏树对棉田主要害虫和自然天敌的影响. 应用昆虫学报, 49(4): 951–956.]
- Wang WL, Liu Y, Ji XL, Wang G, Zhou HB, 2008. Effects of wheat-oilseed rape or wheat-garlic intercropping on the population dynamics of *Sitobion avenae* and its main natural enemies. *Chinese Journal of Applied Ecology*, 19(6): 1331–1336. [王万磊, 刘勇, 纪祥龙, 王光, 周海波, 2008. 小麦间作大蒜或油菜对麦长管蚜及其主要天敌种群动态的影响. 应用生态学报, 19(6): 1331–1336.]
- Wang YH, Zhu XB, Jin YX, Duan RC, Gu YK, Liu XW, Qian L, Chen FJ, 2023. Selection behavior and OBP-transcription response of western flower thrips, *Frankliniella occidentalis*, to six plant VOCs from kidney beans. *International Journal of Molecular Sciences*, 24(16): 12789.
- Wei JW, Liu L, Wang SS, Chen LX, Jiang MJ, Wang GH, Xu HH, 2022. Effects of resistant and susceptible alfalfa varieties on adaptability and enzyme activity of pea aphid. *Acta Agrestia Sinica*, 30(5): 1171–1177. [魏江文, 刘磊, 王森山, 陈丽霞, 蒋明君, 王庚浩, 徐亨昊, 2022. “抗”“感”苜蓿品种对豌豆蚜适应性及体内酶活的影响. 草地学报, 30(5): 1171–1177.]
- Wu CB, Liu FY, Liu JX, Di N, Wang S, Jin ZY, Xu QX, 2022. Role of *Lagopsis supine* in conserving the arthropod natural enemies of pests. *Chinese Journal of Applied Entomology*, 59(2): 303–310. [吴长兵, 刘飞宇, 刘俊秀, 邸宁, 王甦, 金振宇, 徐庆宣, 2022. 夏至草对天敌昆虫控害能力的促进作用. 应用昆虫学报, 59(2): 303–310.]
- Wu KM, Ji HQ, Chen GT, Jin GL, Liu P, 1989. Ecological effect of planting corn in cotton field to protect natural enemies. *Journal of Henan Agricultural Sciences*, 1989(2): 38–39. [吴孔明, 纪好勤, 程广涛, 靳广良, 刘平, 1989. 棉田点种玉米保护天敌的生态效应. 河南农业科学, 1989(2): 38–39.]
- Wu KM, Lu YH, Feng HQ, Jiang YY, Zhao JZ, 2008. Suppression of cotton bollworm in multiple crops in China in areas with Bt toxin-containing cotton. *Science*, 321(5896): 1676–1678.
- Wu SY, Xu LR, Li N, Wang DJ, Lei ZR, 2019. Natural enemy diversity on trapping crops and its application for control of aphids in greenhouse cucumber. *Scientia Agricultura Sinica*, 49(15): 2955–2964. [吴圣勇, 徐丽荣, 李宁, 王登杰, 雷仲仁, 2019. 天敌昆虫在诱集植物上的多样性及对温室蚜虫的防治作用. 中国农业科学, 49(15): 2955–2964.]
- Wu YK, 2018. Habitat selection behavior of adult lacewings and *Orius* spp. Master dissertation. Nanchang: Jiangxi Agricultural University. [吴月坤, 2018. 草蛉与小花蝽成虫的植物生境选择行为. 硕士学位论文. 南昌: 江西农业大学.]
- Wu YK, Liu B, Pan HS, Xiao HJ, Lu YH, 2019. Population densities of *Orius* spp. on different plant species. *Chinese Journal of Biological Control*, 35(4): 527–535. [吴月坤, 刘冰, 潘洪生, 肖海军, 陆宴辉, 2019. 小花蝽在不同植物上的种群密度. 中国生物防治学报, 35(4): 527–535.]
- Xiao YL, Cai ZP, Zhang XR, 2020. Selection, configuration and application of functional plants in orchards. *Chinese Journal of Applied Entomology*, 57(1): 49–58. [肖云丽, 蔡志平, 张兴瑞, 2020. 果园功能植物的筛选、配置及应用. 应用昆虫学报, 57(1): 49–58.]
- Xie X, 2020. Safety evaluation of eight herbicides on *Suaeda glauca* and two natural enemies. Master dissertation. Shihezi: Shihezi University. [谢欣, 2020. 八种除草剂对碱蓬及二种天敌昆虫的安全性评价. 硕士学位论文. 石河子: 石河子大学.]
- Xiong B, 2022. Analysis on pest control and feeding value of alfalfa. *The Chinese Livestock and Poultry Breeding*, 18(5): 51–52. [熊兵, 2022. 紫花苜蓿的病虫草防治及饲用价值分析. 中国畜禽种业, 18(5): 51–52.]
- Xiu CL, Dai WJ, Pan HS, Zhang W, Luo SP, Wyckhuys KAG, Yang YZ, Lu YH, 2019. Herbivore-induced plant volatiles enhance field-level parasitism of the mirid bug *Apolygus lucorum*. *Biological Control*, 135: 41–47.
- Yang N, Hua JN, Zhang JB, Liu D, Bhople P, Li XX, Zhang Y, Ruan HH, Xing W, Mao LF, 2022. Soil nutrients and plant diversity affect ectomycorrhizal fungal community structure and functional traits across three subalpine coniferous forests. *Frontiers in Microbiology*, 13: 1016610.
- Yang QF, Li Z, Ouyang F, Men XY, Zhang KN, Liu M, Guo W, Zhu CG, Zhao WL, Reddy GVP, Ge F, 2023. Flower strips promote natural enemies, provide efficient aphid biocontrol, and reduce insecticide requirement in cotton crops. *Entomologia Generalis*, 43(2): 421–432.

- Yang QF, Men XY, Zhao WL, Li C, Zhang QQ, Cai ZP, Ge F, Ouyang F, 2021. Flower strips as a bridge habitat facilitate the movement of predatory beetles from wheat to maize crops. *Pest Management Science*, 77(4): 1839–1850.
- Yang QF, Ouyang F, Men XY, Ge F, 2018. Discovery and utilization of a functional plant, rich in the natural enemies of insect pests, in northern China. *Chinese Journal of Applied Entomology*, 55(5): 942–947. [杨泉峰, 欧阳芳, 门兴元, 戈峰, 2018. 北方富含天敌的功能植物的发现与应用. 应用昆虫学报, 55(5): 942–947.]
- Yang QF, Ouyang F, Men XY, Ge F, 2020. Functional plants: Current uses and future research. *Chinese Journal of Applied Entomology*, 57(1): 41–48. [杨泉峰, 欧阳芳, 门兴元, 戈峰, 2020. 功能植物的作用原理、方式及研究展望. 应用昆虫学报, 57(1): 41–48.]
- Yang S, Xue S, Shan L, Fan SS, Sun L, Dong YM, Li S, Gao YM, Qi Y, Yang L, An MH, Wang F, Pan JA, Zhang WZ, Weng YQ, Liu XW, Ren HZ, 2024. The CsTM alters multicellular trichome morphology and enhances resistance against aphid by interacting with CsTIP1;1 in cucumber. *Journal of Advanced Research*, 69: 17–30.
- Yan ZF, Zhang C, Wang ZY, He KL, Bai SX, 2012. Predatory function of *Propylaea japonica* on *Rhopalosiphum maidis*. *Plant Protection*, 38(3): 40–43. [闫占峰, 张聪, 王振营, 何康来, 白树雄, 2012. 龟纹瓢虫对玉米蚜的捕食作用研究. 植物保护, 38(3): 40–43.]
- Ye C, An X, Xie BQ, Ding BY, Niu JZ, Wang JJ, 2023. The involvement of systemic RNA interference deficient-1-like (SIL1) in cellular dsRNA uptake in *Acyrtosiphon pisum*. *Insect Science*, 30(5): 1393–1404.
- Yu LB, Lin KJ, Xu LB, Wang H, Cui J, Zhang QY, Wang YP, Yan LY, 2022. Effect of different alfalfa cultivars on growth and development of the spotted alfalfa aphid, *Therioaphis trifolii* (Monell). *Entomological Research*, 52(3): 118–126.
- Yu LB, Yue FZ, Chen TT, Wang YT, Cui J, Xu LB, 2021. Resistance of different alfalfa cultivars to *Therioaphis trifolii* (Hemiptera: Drepanosiphidae) analyzed by EPG technology. *Acta Entomologica Sinica*, 64(11): 1293–1304. [于良斌, 岳方正, 程通通, 王予彤, 崔进, 徐林波, 2021. 应用 EPG 技术分析不同品种苜蓿对苜蓿斑蚜的抗性. 昆虫学报, 64(11): 1293–1304.]
- Yue YH, Qi X, Wang YR, Peng LQ, Yu L, 2014. Persistence of 35 *Medicago sativa* varieties at the 10th year after establishment. *Acta Prataculturae Sinica*, 23(1): 58–64. [岳彦红, 齐晓, 王彦荣, 彭岚清, 余玲, 2014. 35 个 10 龄紫花苜蓿品种的持久性比较. 草业学报, 23(1): 58–64.]
- Zeng J, Jiang YY, Liu J, 2018. The regional pattern of *Loxostege sticticalis* L. varied during a new occurrence intermission in China. *Acta Ecologica Sinica*, 38(5): 1832–1840. [曾娟, 姜玉英, 刘杰, 2018. 我国草地螟发生间歇期的区域格局变化. 生态学报, 38(5): 1832–1840.]
- Zhang AN, Zhou WJ, Wu DX, Zhu L, Fan D, Han LL, Zhao KJ, 2022a. Impact of olfactory and visual cues of soybean aphid on the metabolism and stress resistance of *Orius sauteri* (Poppius). *Biological Control*, 173: 105004.
- Zhang B, Zhou MQ, Wang J, Pu Y, Zhang L, Yuan ML, 2016. Species checklist and research status of alfalfa insect pests reported in China. *Pratacultural Science*, 33(4): 785–812. [张奔, 周敏强, 王娟, 蒲毅, 张丽, 袁明龙, 2016. 我国苜蓿害虫种类及研究现状. 草业科学, 33(4): 785–812.]
- Zhang CR, Wang C, Maggi F, Li S, Meng YL, Luo SL, Yang SY, Cao Y, 2022b. Visual and olfactory preferences of *Frankliniella occidentalis* (Thysanoptera: Thripidae) for color and volatiles of different *Rosa chinensis* (Rosales: Rosaceae) cultivars. *Oriental Insects*, 56(3): 345–361.
- Zhang HB, Zhou FC, Gu AX, Zhang F, Wu YH, Han DB, 2019. The control effect of planting *Chrysanthemum coronarium* around broad bean on *Aphis craccivora*. *Journal of Biosafety*, 28(4): 254–258. [张海波, 周福才, 顾爱祥, 张芳, 郭亚红, 韩杜斌, 2019. 种植茼蒿对蚕豆苜蓿蚜的田间控制作用. 生物安全学报, 28(4): 254–258.]
- Zhang HX, Huo WJ, Chen L, Liu Q, Zhang SL, Wang C, Xu QF, Guo G, 2022. Effects of additives on the fermentation quality and the absorption of amino acids in the intestine of alfalfa silage. *Acta Agrestia Sinica*, 30(5): 1302–1309. [张海铉, 霍文婕, 陈雷, 刘强, 张拴林, 王聪, 许庆方, 郭刚, 2022. 添加剂对紫花苜蓿青贮品质及小肠可吸收氨基酸的影响. 草地学报, 30(5): 1302–1309.]
- Zhang L, Jiang XF, 2022. Occurrence tendency and management strategies of the of the beet webworm *Loxostege sticticalis* in China. *Plant Protection*, 48(4): 68–72. [张蕾, 江幸福, 2022. 我国草地螟发生趋势与防控策略. 植物保护, 48(4): 68–72.]
- Zhang QQ, Liang QW, Na RS, Yang XF, Pan XL, Li QQ, 2022. Evaluation of resistance of 22 alfalfa varieties to thrips and aphids in Ar Horqin Banner Area. *Heilongjiang Animal Science and Veterinary Medicine*, 2022(1): 103–106. [张晴晴, 梁庆伟, 娜日苏, 杨秀芳, 潘翔磊, 李清泉, 2022. 阿鲁科尔沁旗地区 22 个苜蓿品种对蓟马和蚜虫的抗性评价. 黑龙江畜牧兽医, 2022(1): 103–106.]
- Zhang XM, Yang ZB, Zhao ZH, Chen B, Du GZ, Chen GH, 2020. Community composition and activity rhythm of dominant

- flower-visiting insects from different flowering plants in tea gardens. *Chinese Journal of Ecology*, 39(7): 2364–2373. [张晓明, 杨智斌, 赵子华, 陈斌, 杜广祖, 陈国华, 2020. 茶园不同显花植物访花昆虫群落组成及优势种活动规律. 生态学杂志, 39(7): 2364–2373.]
- Zhang YX, Zhang TW, Shi L, Yuan Y, Liu CZ, 2023. Effects of exogenous melatonin on the growth and reproduction of *Aphis craccivora*. *Chinese Journal of Ecology*, 42(5): 1150–1154. [张育霞, 张廷伟, 史历, 袁月, 刘长仲, 2023. 外源褪黑素对苜蓿蚜生长发育和繁殖的影响. 生态学杂志, 42(5): 1150–1154.]
- Zhao XD, Cui XN, Hu GX, 2022. Scanning electron microscopic observations of antennal sensilla in *Odontothrips loti* adults. *Journal of Environmental Entomology*, 44(2): 499–508. [赵晓东, 崔晓宁, 胡桂馨, 刘艳君, 温雅洁, 2022. 牛角花齿蓟马成虫触角感器的扫描电镜观察. 环境昆虫学报, 44(2): 499–508.]
- Zhao XY, Fu XW, Ali A, Wilson K, Wu KM, 2016. Is *Heliothis virescens* (Lepidoptera: Noctuidae) a long-distance migrant? *Bulletin of Entomological Research*, 106(6): 740–748.
- Zhao XM, Wang LD, Zheng X, Li QC, Wang LX, Lan Y, Liu Y, Liu Y, Wang ZY, 2024. Occurrence dynamics of *Monolepta hieroglyphica* and *Harmonia axyridis* in corn fields with different straw returning methods. *China Plant Protection*, 44(3): 27–31, 37. [赵秀梅, 王立达, 郑旭, 李青超, 王连霞, 兰英, 刘悦, 刘洋, 刘颖, 王振营, 2024. 不同秸秆还田方式玉米田双斑萤叶甲和瓢虫发生动态. 中国植保导刊, 44(3): 27–31, 37.]
- Zheng XS, Lu YH, Zhong LQ, Huang XF, Xu FS, Yao XM, Xu HX, Lü ZX, 2017. Optimal planting pattern of trap plant vetiver grass, *Vetivera zizanioides*, for controlling rice striped stemborer, *Chilo suppressalis*. *Plant Protection*, 43(6): 103–108. [郑许松, 鲁艳辉, 钟列权, 黄贤夫, 徐法三, 姚晓明, 徐红星, 吕仲贤, 2017. 诱虫植物香根草控制水稻二化螟的最佳田间布局. 植物保护, 43(6): 103–108.]
- Zhong BZ, Lv CJ, Qin WQ, Pan YY, Yan W, 2020. Preliminary effect of different color plates and additives on the trapping of pests in betel nut orchard. *Plant Protection*, 46(5): 286–289. [钟宝珠, 吕朝军, 覃伟权, 潘月云, 阎伟, 2020. 不同种类色板与添加物协同对槟榔园害虫诱集的初步效果. 植物保护, 46(5): 286–289.]
- Zhu MM, Huang GW, Zhang R, Luo XL, 2019. Investigations of environmental incentives of *Odonothrips loti* outbreaks for alfalfa in mountain area of southern ningxia. *Journal of Ningxia Agriculture and Forestry Science and Technology*, 60(10): 30–32. [朱猛蒙, 黄文广, 张蓉, 罗晓玲, 2019. 宁南山区苜蓿牛角花齿蓟马暴发生态诱因初探. 宁夏农林科技, 60(10): 30–32.]
- Zhu MM, Liu Y, Zhang R, Huang WG, 2013. Canonical correlations between pests and natural enemies and their niches in alfalfa grasslands. *Acta Prataculturae Sinica*, 22(6): 159–166. [朱猛蒙, 刘艳, 张蓉, 黄文广, 2013. 苜蓿草地害虫–天敌典型相关及生态位分析. 草业学报, 22(6): 159–166.]
- Zhu MM, Ma R, Zhang R, 2006. Effect of mowing on alfalfa pests and diseases. *China Plant Protection*, 26(12): 8–10. [朱猛蒙, 马锐, 张蓉, 2006. 刈割对紫花苜蓿病虫害的影响. 中国植保导刊, 26(12): 8–10.]
- Zhu MM, Sun YR, Zhang R, Yu Z, Huang WG, 2011. Preliminary study technique on area forecast of *Therioaphis trifolii* based on GIS. *Acta Prataculturae Sinica*, 20(2): 163–169. [朱猛蒙, 孙玉荣, 张蓉, 于钊, 黄文广, 2011. 基于 GIS 的苜蓿斑蚜区域化预测预报技术初步研究. 草业学报, 20(2): 163–169.]