

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*

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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

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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

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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栽作物。

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>Nephoteryx 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 rondoi</i>
	斑蚜科 Callaphididae	苜蓿斑蚜 <i>Therioaphis trifolii</i>
		大青叶蝉 <i>Cicadella viridis</i>
	叶蝉科 Cicadellidae	小绿叶蝉 <i>Empoasca flavescens</i>
		牧草盲蝽 <i>Lygus pratensis</i>
半翅目 Hemiptera	盲蝽科 Miridae	苜蓿盲蝽 <i>Adelphocoris lineolatus</i>
		绿盲蝽 <i>Lygus lucorum</i>
		三点盲蝽 <i>Adelphocoris fasicollis</i>
		中黑盲蝽 <i>Adelphocoris suturalis</i>
		亚洲小车蝗 <i>Oedaleus decorusasiaticus</i>
		东亚飞蝗 <i>Locusta migratoria migratorioides</i>
直翅目 Mantodea	斑翅蝗科 Oedipodidae	东方蝼蛄 <i>Gryllotalpa burmeister</i>
	蝼蛄科 Gryllotalpidae	

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	
			<i>Megalurothrips usitatus</i>	
	饭豇豆	外围种植	中黑盲蝽	
	<i>Vigna unguiculata</i>	Peripheral planting	<i>Adelphocoris suturalis</i>	
	绿豆	外围种植	绿盲蝽	
	<i>Vigna radiata</i>	Peripheral planting	<i>Apolygus lucorum</i>	
	蚕豆	间作	豌豆蚜	Martin <i>et al.</i> , 2021
	<i>Vicia faba</i>	Row intercropping	<i>Acyrtosiphon pisum</i>	
	草木樨	外围种植	苜蓿盲蝽	
	<i>Melilotus officinalis</i>	Peripheral planting	<i>Adelphocoris lineolatus</i>	
				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 <i>Ladybug</i> , 草蛉 <i>Chrysopa perla</i>	赵秀梅等, 2024
	燕麦 <i>Avena sativa</i>	间作 Row intercropping	瓢虫 <i>Ladybug</i> , 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 <i>Ladybug</i> , 草蛉 <i>Chrysopa perla</i> , 食蚜蝇 <i>Aphid-eating flies</i>	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 <i>Aphid-eating flies</i>	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 <i>Ladybug</i> , 黑带食蚜蝇 <i>Episyrphus balteata</i> , 寄生蜂 <i>Parasitoids</i>	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 <i>Aphid-eating flies</i>	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。

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