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成坪高尔夫草坪上一年生早熟禾的化学防除研究进展

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摘要: 一年生早熟禾属禾本科草本植物, 已成为成坪高尔夫草坪上一种重要杂草, 严重影响草坪的使用价值。目前化学除草剂和植物生长调节剂是控制一年生早熟禾的主要措施。本研究详细总结了高尔夫草坪上一年生早熟禾的发生特点、危害及最佳防治时间, 对可安全用于不同草坪草上防除一年生早熟禾的化学除草剂和植物生长调节剂有效成分信息和田间应用案例进行全面梳理, 指出存在的问题并提出相应对策。结果表明, 芽前组合氨氟乐灵、氟草胺+氟乐灵、氟硫草定、氟硫草定+异噁酰草胺、氟草胺、二甲戊灵、氨氟乐灵+异噁酰草胺、氨氟乐灵+二氯喹啉酸、氨氟乐灵+甲磺草胺、methiozolin、地散磷+噁草酮可安全用于匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、狗牙根和结缕草; 氨氟乐灵、二甲戊灵、氨氟乐灵+异噁酰草胺、氨氟乐灵+甲磺草胺、苄嗪氟草胺、二甲酚草胺+二甲戊灵可安全应用于海滨雀稗、假俭草、野牛草和百喜草。芽后除草剂methiozolin、氨唑草酮、磺酰磺隆可安全用于匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草和海滨雀稗; 氨唑草酮和磺酰磺隆可安全用于假俭草、野牛草、圣奥古斯丁草和百喜草。同时指出目前国内一年生早熟禾的防除存在重苗后轻芽前、防治时间错误等问题, 提出一年生早熟禾的防除应以芽前封闭为主, 芽后早期使用植物生长调节剂和低剂量除草剂混用的施药方式, 能够最大程度减少化学除草剂对草坪草的伤害。

关键词: 高尔夫草坪; 杂草; 一年生早熟禾; 除草剂; 植物生长调节剂; 化学防除

Research progress on the chemical control of annual bluegrass in established golf turf

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Abstract: Annual bluegrass (*Poa annua*) is a herbaceous plant belonging to the Poaceae. It has become a prominent weed in established golf turf, which seriously affects the use value of turf. At present, chemical herbicides and plant growth regulators are the main methods to control annual bluegrass. In this paper, we summarize the occurrence characteristics, hazards and the optimal chemical control time of annual bluegrass. In addition, we review information about field application cases and the active ingredients of chemical herbicides and plant growth regulators that can be safely control annual bluegrass in different turfgrasses. We highlight the existing problems and propose strategies to address them. Among the preemergence herbicides, prodiamine, benefin+trifluralin, dithiopyr, dithiopyr+isoxaben, benefin, pendimethalin, prodiamine+isoxaben, prodiamine+quinclorac, prodiamine+sulfentrazone, methiozolin, and bensulide+oxadiazon can be safely applied to creeping bentgrass (*Agrostis palustris*), tall fescue (*Festuca arundinacea*), kentucky bluegrass (*Poa pratensis*), perennial ryegrass (*Lolium*

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perenne), bermudagrass (*Cynodon dactylon*), and zoysiagrass (*Zoysia japonica*). Prodiamine, pendimethalin, prodiamine+isoxaben, prodiamine+sulfentrazone, indaziflam, and dimethenamid+pendimethalin can be safely applied to seashore paspalum (*Paspalum vaginatum*), centipedegrass (*Eremochloa ophiuroides*), buffalograss (*Buchloe dactyloides*) and bahiagrass (*Paspalum notatum*). Among the postemergence herbicides, methiozolin, amicarbazone and sulfosulfuron can be safely applied to creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, fine fescue (*Festuca rubra*), bermudagrass, zoysiagrass, and seashore paspalum. Amicarbazone and sulfosulfuron can be safely applied to centipedegrass, buffalograss, st. augustinegrass (*Stenotaphrum secundatum*) and bahiagrass. Two current problems in China are the reliance on postemergence control and the incorrect timing of application of chemicals to control annual bluegrass. We propose that preemergence herbicides should be used to control annual bluegrass. Furthermore, we recommend applying a combination of plant growth regulators and low-dose herbicides during the early postemergence stages to decrease damage to turfgrass.

Key words: golf turf; weed; annual bluegrass; herbicide; plant growth regulator; chemical control

草坪是高尔夫球场的核心元素,其质量的高低决定了球场品质,而杂草的控制又是影响草坪质量的重要因素之一。近年来一年生早熟禾(*Poa annua*)发生日趋严重,已成为国内外高尔夫运动草坪上的重要杂草之一^[1-3]。国内外高尔夫球场常用的草坪草有匍匐剪股颖(*Agrostis palustris*)、高羊茅(*Festuca arundinacea*)、肯塔基早熟禾(*Poa pratensis*)、多年生黑麦草(*Lolium perenne*)、细羊茅(*Festuca rubra*)、狗牙根(*Cynodon dactylon*)、结缕草(*Zoysia japonica*)、海滨雀稗(*Paspalum vaginatum*)、假俭草(*Eremochloa ophiuroides*)、野牛草(*Buchloe dactyloides*)、地毯草(*Axonopus compressus*)、圣奥古斯丁草(*Stenotaphrum secundatum*)和百喜草(*Paspalum notatum*)。一年生早熟禾的化学防除分为芽前和芽后2种处理方式,常用的芽前除草剂如氟乐灵、二甲戊灵、氟硫草定、氟乐灵+异噁酰草胺对大部分草坪草具有较高的安全性,施用后会形成0.5~1.5 cm厚的药膜层来抑制杂草种子的萌发,而健康成坪草坪草的根系长度通常大于5 cm,因此草坪草根系吸收较少的药剂而具有较高的安全性。由于常用草种和一年生早熟禾均属于禾本科草本植物,依据生理和生化选择性原理,芽后防除时则需要施用选择性指数更高的药剂,通常选择草坪草吸收较少或者对其代谢解毒能力较强的药剂,使其对草坪草安全而能有效防除一年生早熟禾。一年生早熟禾具有发芽周期长、耐低修剪、易抽穗开花、种子产量高等特点,据报道低密度生长条件下一株一年生早熟禾可产生80个花序,同时在修剪高度为3 mm的果岭上可产生头穗并形成种子,从而导致土壤中种子量增加^[4-5]。果岭上的一年生早熟禾则会降低高尔夫球的滚动速度,降低草坪的可打性^[6]。由于其颜色为浅绿色,会在深绿色草坪如匍匐剪股颖草坪上形成浅绿斑,导致草坪的景观价值大幅下降。除此之外,其在温度适宜时能够快速生长,与草坪草争夺养分、水分、光照,严重抑制草坪草的生长^[7]。目前一年生早熟禾的控制仍然依赖化学除草剂,除此之外,植物生长调节剂如抗倒酯、咪唑醇、多效唑和乙烯利也被用于控制一年生早熟禾^[2,8],其能够有效抑制一年生早熟禾抽穗,减少种子基数^[2]。目前国内未见有专业登记防除高尔夫草坪上一年生早熟禾的药剂,但草坪管理者会利用一些未登记的药剂进行防除,而这些药剂通常没有详细的使用说明,使用不当则会产生药害。因此本研究查阅国内外相关资料,对可安全用于不同草坪草上防除一年生早熟禾的化学除草剂和植物生长调节剂有效成分信息和田间应用案例进行全面梳理,指出存在的问题并提出相应对策,以期为我国草坪管理者防除一年生早熟禾提供借鉴和帮助。

1 发生特点、危害及最佳防治时间

一年生早熟禾原产于欧洲,属冬季性杂草,通常在秋冬季节萌发出苗^[9-11],我国区域内的一年生早熟禾有2个出苗高峰期,分别为10-12月和2-3月,有研究表明一年生早熟禾在4~32℃均可发芽,但随着温度的升高发芽率会下降,最适的发芽温度为20~24℃^[12],萌发的种子经过秋冬季节的生长,在次年3-6月开花结籽,然后自然死亡。一年生早熟禾成熟主要靠种子繁殖,成熟的种子落地之后休眠3~4个月,环境条件适宜时继续萌发。当暖季型草坪处于旺盛生长状态时,由于一年生早熟禾的耐热性较差,死亡后在草坪上形成枯斑,严重影响草坪景

观效果,同时其还可以破坏草坪的完整性,降低球速^[13-14];当其处于休眠状态,一年生早熟禾则处于生长状态并会对暖季型草坪快速侵占,导致其成为优势草种,破坏草坪的统一性^[10]。我国地域辽阔,环境因素相差较大,一年生早熟禾的出苗时间也会有所差异,通常北方出苗早于南方,芽前防除时间通常在6—9月进行,华中、华东和南方区域可在12月到次年2月进行第二次芽前处理,能够有效抑制春季萌发的种子。苗后茎叶处理的时间通常为10—12月和2—3月,在其未分蘖抽穗之前进行茎叶处理,在春季施药的基础上增加一次秋季处理,能够提高一年生早熟禾的防除效果^[2]。

2 可用化学药剂有效成分分类

按照除草剂使用时间不同将其细分为芽前、芽后和芽前兼芽后除草剂,芽前除草剂有二硝基苯胺类(氨氟乐灵、氨磺乐灵、二甲戊灵、氟草胺、氟乐灵)、吡啶类(氟硫草定)、噁二唑酮类(噁草酮)、N-苯基酰胺类(丙炔氟草胺)、 α -氯化乙酰氨基类(异丙甲草胺、二甲酚草胺)、三酮类(硝磺草酮)、二硫代磷酸酯类(地散磷)、苯酰胺类(异噁酰草胺)、三嗪类(苄嘧氟草胺)9类药剂。芽后除草剂有磺酰脲类(啶嘧磺隆、甲酰胺基磺隆、甲磺隆、砒嘧磺隆、磺酰磺隆、噻酮磺隆、氯吡嘧磺隆、三氟啶磺隆)、嘧啶水杨酸类(双草醚)、咪唑啉酮类(咪唑啉酸)、三唑啉酮类(氨唑草酮)、有机磷类(草甘膦)5类药剂。芽前兼芽后除草剂有苯酰胺类(戊炔草胺)、三氮苯类(莠去津、西玛津)、三嗪酮类(噻草酮)、三唑啉酮类(甲磺草胺)、苯丙咪唑类(乙氧氟草磺)和苯甲醚类(methiozolin)6类药剂^[15-16]。除草剂抗性行动委员会根据作用机制赋予不同除草剂不同的抗性代码(表1),便于使用者混配使用,能够延缓抗性的产生。除此之外,部分植物生长调节剂也可用于调控一年生早熟禾(表2),主要机制为抑制其抽穗开花,降低其种子产量,常用的调节剂主要有有机磷类(乙烯利)、三唑类(多效唑)、环己烷羧酸类(抗倒酯)、含氮杂环类(咪唑醇)4类药剂。

3 不同草坪草上登记使用的芽前除草剂组合及应用防除案例

芽前除草是控制成坪高尔夫草坪上一年生早熟禾的基础措施。芽前除草原理是在种子未萌发之前将药剂均匀地施于土壤并形成0.5~1.5 cm厚的药膜层,当杂草种子萌发时触药死亡^[45]。芽前除草剂的施用能够降低种子出苗率。通过查阅国内外资料,对可用于防除一年生早熟禾的芽前组合信息进行了详细的总结(表3),结果表明,芽前组合氨氟乐灵、氟草胺+氟乐灵、氟硫草定、氟硫草定+异噁酰草胺、氟草胺、二甲戊灵、氨氟乐灵+异噁酰草胺、氨氟乐灵+二氯喹啉酸、氨氟乐灵+甲磺草胺、methiozolin、地散磷+噁草酮可安全用于匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、狗牙根和结缕草;氨氟乐灵、二甲戊灵、氨氟乐灵+异噁酰草胺、氨氟乐灵+甲磺草胺、苄嘧氟草胺、二甲酚草胺+二甲戊灵可安全应用在海滨雀稗、假俭草、野牛草和百喜草。除此之外,表3中的其他芽前组合均可应用于狗牙根草坪和结缕草(乙氧氟草磺和噻草酮不能用于结缕草)。修剪高度大于1.27 cm的匍匐剪股颖才可使用芽前除草剂,否则会对其造成伤害^[17]。芽前除草剂施用方式为土壤喷雾,施用之后需要及时浇水,使药剂渗入土壤起作用。

成坪高尔夫草坪上一年生早熟禾的芽前化学防除技术相对成熟,Carroll等^[10]的研究表明芽前施用二甲戊乐灵($2.24 \text{ kg}\cdot\text{hm}^{-2}$) + 二甲酚草胺($1.68 \text{ kg}\cdot\text{hm}^{-2}$)能够有效控制狗牙根草坪上的一年生早熟禾,施用23周以后的防除效果为88%~100%,且混用的防除效果优于戊炔草胺、西玛津、二甲戊灵和二甲酚草胺单独使用。Brosnan等^[47]的研究表明苄嘧氟草胺($0.03\sim 0.06 \text{ kg}\cdot\text{hm}^{-2}$)对狗牙根草坪上一年生早熟禾防除效果为67%~100%。Reicher等^[48]利用硝磺草酮+氨氟乐灵或乙氧氟草磺+氨氟乐灵组合对肯塔基早熟禾草坪中一年生早熟禾取得较好的芽前防除效果。Askew等^[49]的研究表明methiozolin、苄磺隆、地散磷、地散磷+噁草酮芽前组合对匍匐剪股颖安全,其中methiozolin($0.50\sim 0.75 \text{ kg}\cdot\text{hm}^{-2}$)和苄磺隆($8.60 \text{ kg}\cdot\text{hm}^{-2}$)的芽前防除效果优于地散磷($9.00 \text{ kg}\cdot\text{hm}^{-2}$)和地散磷($8.60 \text{ kg}\cdot\text{hm}^{-2}$) + 噁草酮($2.15 \text{ kg}\cdot\text{hm}^{-2}$)组合,且methiozolin并不能快速控制一年生早熟禾,但其可以有效抑制85%以上的植株抽穗。Yu等^[50]通过研究根茎建植的早熟禾草坪上一年生早熟禾的芽前控制方案,表明乙氧氟草磺($0.84 \text{ kg}\cdot\text{hm}^{-2}$)或噁草酮(1.12 或 $2.24 \text{ kg}\cdot\text{hm}^{-2}$)对一年生早熟禾的防除效果达67%~75%。

表1 可用于成坪高尔夫草坪防除一年生早熟禾的除草剂有效成分信息

Table 1 Information of the active ingredients of herbicides that can be used to control annual bluegrass in established golf turf

除草剂 类型 Herbicide type	化学分类 Chemical group	有效成分 Active ingredients	HRAC分 组代码 HRAC group code	作用方式 Mode of action	参考 文献 Refer- ences	
芽前除 草剂 Preemer- gence her- bicide	二硝基苯胺类 Dinitroanilines	氨基乐灵 Prodiamine	3	微管组装抑制剂 Inhibition of microtubule assembly	[17]	
		氨基乐灵 Oryzalin	3	微管组装抑制剂 Inhibition of microtubule assembly	[18]	
		二甲戊灵 Pendimethalin	3	微管组装抑制剂 Inhibition of microtubule assembly	[19]	
		氟草胺 Benfenin	3	微管组装抑制剂 Inhibition of microtubule assembly	[20]	
		氟乐灵 Trifluralin	3	微管组装抑制剂 Inhibition of microtubule assembly	[20]	
吡啶类 Pyridines	氟硫草定 Dithiopyr	3	微管组装抑制剂 Inhibition of microtubule assembly	[21]		
噁二唑酮类 N-phenyl-oxadiazolones	噁草酮 Oxadiazon	14	原卟啉原氧化酶的抑制剂 Inhibition of protoporphyrinogen oxidase	[22]		
N-苯基酰胺类 N-phenyl-imides	丙炔氟草胺 Flumioxazin	14	原卟啉原氧化酶的抑制剂 Inhibition of protoporphyrinogen oxidase	[23]		
α -氯化乙酰氨基类 α -chloroacetamides	异丙甲草胺 Metolachlor	15	长链脂肪酸合成抑制剂 Inhibition of very long-chain fatty acid synthesis	[24]		
α -氯化乙酰氨基类 α -chloroacetamides	二甲酚草胺 Dimethenamid	15	长链脂肪酸合成抑制剂 Inhibition of very long-chain fatty acid synthesis	[25]		
三酮类 Triketones	硝磺草酮 Mesotrione	27	丙酮酸羧基酯双加氧酶抑制剂 Inhibition of hydroxyphenyl pyruvate dioxygenase	[26]		
二硫代磷酸酯类 Phosphorodithioate	地散磷 Bensulide	0	—	[15]		
苯酰胺类 Benzamides	异噁唑草胺 Isoxaben	29	纤维素合成抑制剂 Inhibition of cellulose synthesis	[27]		
三嗪类 Alkylazines	茚啉氟草胺 Indaziflam	29	纤维素合成抑制剂 Inhibition of cellulose synthesis	[28]		
芽后除 草剂 Pos- temer- gence her- bicide	磺酰脲类 Sulfonylureas	啶嘧磺隆 Flazasulfuron	2	乙酰乳酸合酶抑制剂 Inhibition of acetolactate synthase	[15]	
		甲酰胺基磺隆 Foramsulfuron	2	乙酰乳酸合酶抑制剂 Inhibition of acetolactate synthase	[29]	
		甲磺隆 Metsulfuron	2	乙酰乳酸合酶抑制剂 Inhibition of acetolactate synthase	[30]	
		砒嘧磺隆 Rimsulfuron	2	乙酰乳酸合酶抑制剂 Inhibition of acetolactate synthase	[31]	
		磺酰磺隆 Sulfosulfuron	2	乙酰乳酸合酶抑制剂 Inhibition of acetolactate synthase	[32]	
		噻酮磺隆 Thiencarbazone	2	乙酰乳酸合酶抑制剂 Inhibition of acetolactate synthase	[33]	
		氯吡啉磺隆 Halosulfuron	2	乙酰乳酸合酶抑制剂 Inhibition of acetolactate synthase	[33]	
		三氟啉磺隆 Trifloxysulfuron	2	乙酰乳酸合酶抑制剂 Inhibition of acetolactate synthase	[34]	
嘧啶水杨酸类 Pyrimidinyl benzoates	双草醚 Bispyribac	2	乙酰乳酸合酶抑制剂 Inhibition of acetolactate synthase	[35]		
咪唑啉酮类 Imidazolinones	咪唑啉酸 Imazaquin	2	乙酰乳酸合酶抑制剂 Inhibition of acetolactate synthase	[15]		
三唑啉酮类 Triazolinone	氨基草酮 Amicarbazone	5	光系统 II 抑制剂 Inhibition of photosynthesis PS II	[36]		
有机磷类 Organophosphorus	草甘膦 Glyphosate	9	烯醇丙酮酰莽草酸磷酸合酶抑制剂 Inhibition of enolpyruvyl shikimate phosphate synthase	[37]		
芽前兼 芽后 Pre/ postemer- gence her- bicide	苯酰胺类 Benzamides	戊炔草胺 Pronamide	3	微管组装抑制剂 Inhibition of microtubule assembly	[15]	
		三氮苯类 Triazines	莠去津 Atrazine	5	光系统 II 抑制剂 Inhibition of photosynthesis PS II	[38]
		三嗪酮类 Triazinones	噻草酮 Metribuzin	5	光系统 II 抑制剂 Inhibition of photosynthesis PS II	[39]
		三氮苯类 Triazines	西玛津 Simazine	5	光系统 II 抑制剂 Inhibition of photosynthesis PS II	[40]
		三唑啉酮类 N-phenyl-triazolinones	甲磺草胺 Sulfentrazone	14	原卟啉原氧化酶的抑制剂 Inhibition of protoporphyrinogen oxidase	[41]
		苯丙呋喃类 Benzofurans	乙氧呋草磺 Ethofumesate	15	长链脂肪酸合成抑制剂 Inhibition of very long-chain fatty acid synthesis	[42]
		苯甲醚类 Benzyl ether	Methiozolin	30	脂肪酸硫酯酶合成抑制剂 Inhibition of fatty acid thioesterase	[43]

HRAC: 除草剂抗性行动委员会 Herbicide resistance action committee; —: 表示作用方式未知 Indicates that the mode of action is unknown.

表 2 可用于成坪高尔夫草坪防除一年生早熟禾的植物生长调节剂有效成分信息

Table 2 Information of active ingredients of plant growth regulators that can be used to control annual bluegrass in established golf turf

植物生长调节剂 类型 Plant growth regulator type	化学分类 Chemical group	有效成分 Active ingredients	作用方式 Mode of action	参考文献 Referenc- es
促进剂 Promoter	有机磷类 Organophosphorus	乙烯利 Ethephon	促进蛋白质的合成 Promote protein synthesis	[2]
抑制剂 Inhibitor	三唑类 Triazole	多效唑 Paclobutrazol	赤霉素合成抑制剂 Gibberellin synthesis inhibitors	[4]
	环己烷羧酸类 Cyclohexane carboxylic acids	抗倒酯 Trinexapac-ethyl	赤霉素合成抑制剂 Gibberellin synthesis inhibitors	[2]
	含氮杂环类 Nitrogenous heterocycles	咪唑醇 Flurprimidol	赤霉素合成抑制剂 Gibberellin synthesis inhibitors	[44]

表 3 可用于成坪高尔夫草坪防除一年生早熟禾芽前药剂组合

Table 3 Preemergence herbicide combinations for controlling annual bluegrass in established golf turf

商品名 Trade name	有效成分 Active ingredients	防除效果 Control effect	有效成分用量 Active ingredient dosage ($\text{kg}\cdot\text{hm}^{-2}$)	登记安全应用于草坪草种类 Registration safety applies to turfgrass species	参考文献 Referenc- es
Barri- cade	氨基乐灵 Prodi- amine	G	0.18~0.55	匍匐剪股颖(球道)、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草、海滨雀稗、假俭草、野牛草、圣奥古斯丁草、百喜草 Creeping bentgrass (fairway), tall fescue, kentucky bluegrass, perennial ryegrass, fine fescue, bermudagrass, zoysiagrass, seashore paspalum, centipedegrass, buffalo-grass, st. augustinegrass, bahiagrass	[17]
Team pro	氟草胺+氟乐灵 Benefin+trifluralin	G	(0.85~1.70)+ (0.85~1.70)	匍匐剪股颖(球道)、高羊茅、肯塔基早熟禾、多年生黑麦草、狗牙根、结缕草、假俭草、圣奥古斯丁草、百喜草 Creeping bentgrass (fairway), tall fescue, kentucky bluegrass, perennial ryegrass, bermudagrass, zoysiagrass, centipede-grass, st. augustinegrass, bahiagrass	[20]
Dimen- sion	氟硫草定 Dithiopyr	G	0.14~0.42	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草、假俭草、野牛草、地毯草、圣奥古斯丁草、百喜草 Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, fine fescue, bermudagrass, zoysia-grass, centipedegrass, buffalograss, carpetgrass, st. augustinegrass, bahiagrass	[21]
Crew	氟硫草定+异噁酰 草胺 Dithiopyr+ isoxaben	G	(0.14~0.42)+ (0.56~1.12)	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草、野牛草 Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, fine fescue, bermudagrass, zoysiagrass, buffalograss	[15]
Balan	氟草胺 Benefin	G	1.68~3.36	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草、野牛草 Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, fine fescue, bermudagrass, zoysiagrass, buffalograss	[15]
Ronstar	噁草酮 Oxadiazon	G	0.84~1.68	匍匐剪股颖、高羊茅、多年生黑麦草、狗牙根、结缕草、海滨雀稗、野牛草、圣奥古斯丁草 Creeping bentgrass, tall fescue, perennial ryegrass, bermudag-rass, zoysiagrass, seashore paspalum, buffalograss, st. augustinegrass	[22]
Pendu- lum	二甲戊灵 Pendi- methalin	G	1.68~3.36	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草、海滨雀稗、假俭草、野牛草、圣奥古斯丁草、百喜草 Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, fine fescue, bermudagrass, zoysiagrass, seashore paspalum, centipedegrass, buffalograss, st. augustine-grass, bahiagrass	[19]
Gemini	氨基乐灵+异噁酰 草胺 Prodiamine+ isoxaben	G	(0.18~0.55)+ (0.56~1.12)	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草、海滨雀稗、假俭草、野牛草、圣奥古斯丁草、百喜草 Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, fine fescue, bermudagrass, zoysiagrass, seashore paspalum, centipedegrass, buffalograss, st. augustine-grass, bahiagrass	[27]

续表 Continued Table

商品名 Trade name	有效成分 Active ingredients	防除效果 Control effect	有效成分用量 Active ingredient dosage (kg·hm ⁻²)	登记安全应用于草坪草种类 Registration safety applies to turfgrass species	参考文献 References
Cavalcade	氨基乐灵+二氯喹啉酸 Prodiamine+quinclorac	G	(0.35~1.68)+ (0.56~0.84)	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草、海滨雀稗、野牛草 Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, fine fescue, bermudagrass, zoysiagrass, seashore paspalum, buffalograss	[15]
Echelon	氨基乐灵+甲磺草胺 Prodiamine+sulfentrazone	G	(0.180~0.550)+ (0.092~0.140)	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草、海滨雀稗、假俭草、野牛草、地毯草、百喜草 Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, fine fescue, bermudagrass, zoysiagrass, seashore paspalum, centipedegrass, buffalograss, carpetgrass, bahiagrass	[41]
Poacure	Methiozolin	E	0.52~1.04	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草、海滨雀稗 Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, fine fescue, bermudagrass, zoysiagrass, seashore paspalum	[43]
Goosegrass	地散磷+噁草酮 Bensulide+oxadiazon	G	(3.36~6.72)+ (0.84~1.68)	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、狗牙根、结缕草 Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, bermudagrass, zoysiagrass	[46]
Prograss	乙氧呋草磺 Ethofumesate	G	0.84~2.24	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、休眠期狗牙根、圣奥古斯丁草 Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, dormant bermudagrass, st. augustinegrass	[42]
Surflan flex	氨基乐灵 Oryzalin	E	1.68~2.24	高羊茅、狗牙根、结缕草、假俭草、野牛草、圣奥古斯丁草、百喜草 Tall fescue, bermudagrass, zoysiagrass, centipedegrass, buffalograss, st. augustinegrass, bahiagrass	[18]
Specticle flo	茚嗪氟草胺 Indaziflam	E	0.013~0.020	狗牙根、结缕草、海滨雀稗、假俭草、野牛草、圣奥古斯丁草、百喜草 Bermudagrass, zoysiagrass, seashore paspalum, centipedegrass, buffalograss, st. augustinegrass, bahiagrass	[28]
Surflan xl	氟草胺+氨基乐灵 Benefin+oryzalin	G	(0.85~1.70)+ (1.68~2.24)	高羊茅、狗牙根、结缕草、野牛草 Tall fescue, bermudagrass, zoysiagrass, buffalograss	[15]
Freehand	二甲酚草胺+二甲戊灵 Dimethenamid+pendimethalin	G	(0.84~1.68)+ (1.12~2.24)	狗牙根、结缕草、海滨雀稗、假俭草、野牛草、圣奥古斯丁草、百喜草 Bermudagrass, zoysiagrass, seashore paspalum, centipedegrass, buffalograss, st. augustinegrass, bahiagrass	[25]
Kerb	戊炔草胺 Pronamide	E	0.56~2.24	狗牙根、结缕草、野牛草 Bermudagrass, zoysiagrass, buffalograss	[15]
Princep	西玛津 Simazine	E	1.12~1.79	狗牙根、结缕草、假俭草、圣奥古斯丁草 Bermudagrass, zoysiagrass, centipedegrass, st. augustinegrass	[40]
Pennant magnum	异丙甲草胺 Metolachlor	G	1.39~2.78	狗牙根、结缕草、假俭草、圣奥古斯丁草、百喜草 Bermudagrass, zoysiagrass, centipedegrass, st. augustinegrass, bahiagrass	[24]
Sureguard	丙炔氟草胺 Flumioxazin	E	0.28~0.43	处于休眠期的狗牙根、结缕草、海滨雀稗、假俭草、圣奥古斯丁草 Dormant bermudagrass, zoysiagrass, seashore paspalum, centipedegrass, st. augustinegrass	[23]
Sencor	噻草酮 Metribuzin	E	0.28~0.56	狗牙根 Bermudagrass	[39]
Aatrex	莠去津 Atrazine	E	1.12~2.24	狗牙根、结缕草、假俭草、圣奥古斯丁草 Bermudagrass, zoysiagrass, centipedegrass, st. augustinegrass	[38]

防除效果 E 为极好,防除效果大于 90%;防除效果 G 为好,防除效果为 75%~90%。下同。The control effect E is excellent, and the control effect is greater than 90%. The control effect G is good, and the control effect is between 75% and 90%. The same below.

4 不同草坪草上登记使用的芽后除草剂组合及应用案例

芽前除草剂虽然能够有效降低种子出苗基数,但受药效和人为活动的影响,仍有部分种子发芽出苗。此时需要施用芽后除草剂和植物生长调节剂防除一年生早熟禾,苗后除草的原则遵循“除早除小”,尽量在其分蘖抽穗之前防除。对不同草坪草上可用的芽后药剂组合信息进行梳理(表4),结果表明methiozolin、氨唑草酮、磺酰磺隆可安全用于匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草和海滨雀稗;氨唑草酮和磺酰磺隆可安全用于假俭草、野牛草、圣奥古斯丁草和百喜草。除此之外,乙氧呋草磺可安全用于匍匐剪股颖、高羊茅、肯塔基早熟禾和多年生黑麦草;三氟啶磺隆、啶嘧磺隆、噻酮磺隆+甲酰胺基磺隆+氯吡嘧磺隆可安全用于狗牙根和结缕草草坪,具体有效成分用量见表4。

与芽前除草剂相比,芽后除草剂的使用技术要求相对较高,药剂的种类、施药温度、施用剂量、施药方式、施药器械和用水量均会影响防除效果,因此了解药剂特性和使用方法非常关键。目前国外对匍匐剪股颖、肯塔基早熟禾、多年生黑麦草、狗牙根、海滨雀稗和结缕草草坪上芽后一年生早熟禾防除应用案例较多,这些草种也是我国高尔夫球场的主要草种,对其进行梳理有助于我国草坪管理者较好地防除一年生早熟禾。

4.1 匍匐剪股颖草坪芽后应用防除案例

4.1.1 methiozolin 匍匐剪股颖常用于果岭和球道,可使用的芽后药剂有methiozolin、氨唑草酮、磺酰磺隆、双草醚、乙氧呋草磺、抗倒酯和多效唑等^[2,49,51-52]。Flessner等^[53]的研究表明methiozolin($1.12\text{ kg}\cdot\text{hm}^{-2}$)施用12周以后对一年生早熟禾防除效果高于60%,且硫酸铵和硫酸铁的添加不会影响methiozolin的防效,同时能够降低methiozolin对匍匐剪股颖的伤害程度。methiozolin的防效受温度、施药部位、土壤类型影响,McCullough等^[54]的研究表明methiozolin在温度为 $10\text{ }^{\circ}\text{C}$ 时对匍匐剪股颖的伤害程度分别是 $20\text{ }^{\circ}\text{C}$ 和 $30\text{ }^{\circ}\text{C}$ 的2和4倍,是因为温度升高能够促进methiozolin从根部向茎部转移从而减少伤害,因此推荐 $20\text{ }^{\circ}\text{C}$ 以上施用。Brosnan等^[55]的研究表明根部施用methiozolin比叶面施用防除效果更好,methiozolin($1.00\text{ kg}\cdot\text{hm}^{-2}$)在沙质果岭上的防效比土质果岭低15%~19%。为缓解methiozolin对匍匐剪股颖的伤害作用,Venner等^[56]将methiozolin和其他物质(抗倒酯和生物刺激素)混用,结果表明其能有效降低methiozolin对匍匐剪股颖的影响。Brosnan等^[57]的研究表明methiozolin均能有效控制对其他药剂产生抗性的一年生早熟禾。

4.1.2 氨唑草酮 氨唑草酮属光合作用抑制剂,其能有效控制一年生早熟禾,常与生长调节剂混合使用。Jeffries等^[52]的研究结果表明氨唑草酮($0.049\text{ kg}\cdot\text{hm}^{-2}$)与多效唑($0.070\text{ kg}\cdot\text{hm}^{-2}$)组合连续施用6次(每次间隔7d)对一年生早熟禾的防除效果大于70%,优于单独使用,且多效唑的使用能够提高匍匐剪股颖对氨唑草酮的耐受性。Perry等^[58]的研究表明氨唑草酮($0.53\text{ kg}\cdot\text{hm}^{-2}$)施用3周以后对一年生早熟禾的防除效果为100%,同时还能降低光合量子产量。施药方式和温度也会对其药效有所影响,Jeffries等^[59]研究了不同施用方式(叶片、土壤、叶片+土壤)对氨唑草酮($0.049\text{ kg}\cdot\text{hm}^{-2}$)效果的影响,结果表明其主要通过根系吸收,施用56d以后的防除效果大于60%。McCullough等^[60]的研究表明氨唑草酮的药效随着温度的升高($10\sim 30\text{ }^{\circ}\text{C}$)而增加,但同时也会对匍匐剪股颖的伤害也会增加,因此推荐春季温度较低时连续2~3次施用低剂量氨唑草酮防除一年生早熟禾。

4.1.3 双草醚 McDonald等^[61]研究发现连续施用3次(每次间隔14d)双草醚(0.049 或 $0.111\text{ kg}\cdot\text{hm}^{-2}$)对匍匐剪股颖草坪上的一年生早熟禾防除效果大于82%,螯合铁及氮肥和双草醚的混用能有效缓解匍匐剪股颖褪色问题,且不会影响防效。Branham等^[62]研究了双草醚对匍匐剪股颖幼苗的安全性及对一年生早熟禾的防除效果,推荐在出苗3~5周以后施用双草醚($0.074\text{ kg}\cdot\text{hm}^{-2}$)能够有效控制一年生早熟禾,且对匍匐剪股颖的伤害较小。Reicher等^[63]的研究表明在秋季连续施用2次双草醚对匍匐剪股颖上的一年生早熟禾控制效果较好。

4.1.4 植物生长调节 Baldwin等^[8]研究了抗倒酯、多效唑、咪唑醇3种药剂对匍匐剪股颖上一年生早熟禾的控制,间隔2周施用一次,连续施用2个生长季节,结果表明多效唑($0.28\text{ kg}\cdot\text{hm}^{-2}$)和咪唑醇(0.22 和 $0.28\text{ kg}\cdot\text{hm}^{-2}$)能够有效增加匍匐剪股颖的覆盖度。Woosley等^[64]的研究结果表明多效唑(0.14 和 $0.28\text{ kg}\cdot\text{hm}^{-2}$)对一年生早熟禾的防效大于85%,在春夏季节使用基础上,秋冬季节继续使用乙氧呋草磺也能增强对一年生早熟禾的控制效果。Ervin等^[65]利用多效唑($0.18\sim 0.36\text{ kg}\cdot\text{hm}^{-2}$)和硫酸亚铁($12.2, 24.4, 48.8\text{ kg}\cdot\text{hm}^{-2}$)长期联合控制一

表 4 可用于成坪高尔夫草坪防除一年生早熟禾芽后药剂组合

Table 4 Postemergence herbicide combinations for controlling annual bluegrass in established golf turf

商品名 Trade name	有效成分 Active ingredients	防除效果 Control effect	有效成分用量 Active ingredient dosage (kg·hm ⁻²)	登记安全应用于草坪草种类 Registration safety applies to turfgrass species	参考文献 References
Poacure	Methiozolin	E	0.52~1.04	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草、海滨雀稗、Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, fine fescue, bermudagrass, zoysiagrass, seashore paspalum	[43]
Xonorate	氨基草酮 Amicarbazone	G	0.04~0.10	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草、海滨雀稗、假俭草、野牛草、圣奥古斯丁草、百喜草 Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, fine fescue, bermudagrass, zoysiagrass, seashore paspalum, centipede grass, st. augustine grass, bahiagrass	[36]
Kerb	戊快草胺 Pronamide	G	0.56~2.24	狗牙根、结缕草、野牛草 Bermudagrass, zoysiagrass, buffalograss	[15]
Princep	西玛津 Simazine	G	1.12~2.24	狗牙根、结缕草、假俭草、圣奥古斯丁草 Bermudagrass, zoysiagrass, centipede grass, st. augustine grass	[40]
Katana	啶嘧磺隆 Flazasulfuron	G	0.0089~0.0530	狗牙根、结缕草、野牛草 Bermudagrass, zoysiagrass, buffalograss	[15]
Revolver	甲酰胺基磺隆 Foramsulfuron	E	0.0067~0.0580	狗牙根、结缕草、野牛草 Bermudagrass, zoysiagrass, buffalograss	[29]
Negate	甲磺隆+啶嘧磺隆 Metsulfuron+rimsulfuron	G	(0.020~0.040)+(0.016~0.032)	狗牙根、结缕草 Bermudagrass, zoysiagrass	[15]
Certainty	磺酰磺隆 Sulfosulfuron	G	0.065~0.100	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草、海滨雀稗、假俭草、野牛草、圣奥古斯丁草、百喜草 Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, fine fescue, bermudagrass, zoysiagrass, seashore paspalum, centipede grass, buffalograss, st. augustine grass, bahiagrass	[32]
Monument	三氟啶磺隆 Trifloxysulfuron	E	0.0179~0.0280	狗牙根、结缕草、野牛草、圣奥古斯丁草 Bermudagrass, zoysiagrass, buffalograss, st. augustine grass	[34]
Aatrex	莠去津 Atrazine	E	1.12~2.24	狗牙根、结缕草、假俭草、圣奥古斯丁草 Bermudagrass, zoysiagrass, centipede grass, st. augustine grass	[38]
Tribute total	噻酮磺隆+甲酰胺基磺隆+氟吡啶磺隆 Thiencarbazone+foramsulfuron+halosulfuron	E	(0.0050~0.0100)+(0.0067~0.0580)+(0.0680~0.1400)	狗牙根、结缕草 Bermudagrass, zoysiagrass	[33]
Rimsulfuron	啶嘧磺隆 Rimsulfuron	E	0.0080~0.0336	狗牙根、结缕草、野牛草 Bermudagrass, zoysiagrass, buffalograss	[31]
Campaign	草甘膦+2,4-D Glyphosate+2,4-D	E	(0.81~1.62)+(0.85~1.70)	休眠期的狗牙根 Dormant bermudagrass	[37]
Coastal	西玛津+氨基乐灵+咪唑啉酮 Simezine+proflaminate+imazaquin	G	(1.12~1.79)+(0.18~0.55)+(0.41~0.56)	休眠期的狗牙根、结缕草 Dormant bermudagrass, zoysiagrass	[15]
Sencor	噻草酮 Metribuzin	G	0.28~0.56	狗牙根 Bermudagrass	[39]
Velocity	双草醚 Bispyribac	G	0.02~0.07	匍匐剪股颖、多年生黑麦草 Creeping bentgrass, perennial ryegrass	[35]
Prograss	乙氧呋草醚 Ethofumesate	G	0.84~2.24	匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、休眠期狗牙根、圣奥古斯丁草 Creeping bentgrass, tall fescue, kentucky bluegrass, perennial ryegrass, dormant bermudagrass, st. augustine grass	[42]

年生早熟禾,结果表明2年以后一年生早熟禾的覆盖度仅为5%。Diehl等^[66]的研究表明每月使用多效唑($0.21 \text{ kg}\cdot\text{hm}^{-2}$)使匍匐剪股颖球道上一年生早熟禾的覆盖度小于20%。Reicher等^[63]和Patton等^[67]的研究也表明多效唑对一年生早熟禾的防除效果较好。目前在春季连续施用2次乙烯利是草坪上控制一年生早熟禾的工业标准,研究表明春季施用乙烯利的基础上增加一次秋季乙烯利或抗倒酯的施用,能够使一年生早熟禾的头穗数量降低83%~88%^[2,68]。

4.2 其他冷季型草坪芽后应用防除案例

Rana等^[69]评价了methiozolin对110个肯塔基早熟禾品种的安全性及对一年生早熟禾的防除效果,结果表明methiozolin对肯塔基早熟禾的安全性较好,同时在秋季连续两次施用methiozolin($2.00 \text{ kg}\cdot\text{hm}^{-2}$)能够有效控制一年生早熟禾。硝磺草酮也可用于芽后防除一年生早熟禾,Branham等^[70]的研究表明硝磺草酮少量多次使用对肯塔基早熟禾上一年生早熟禾的控制效果较好。McCullough等^[71]研究表明双草醚($0.22\sim 0.30 \text{ kg}\cdot\text{hm}^{-2}$)对多年生黑麦草和高羊茅草坪上一年生早熟禾的防除效果大于90%,推荐连续少量多次使用双草醚对多年生黑麦草和高羊茅上一年生早熟禾进行控制。助剂的使用会增强防效,能够有效降低除草剂的用量,延缓抗性的产生。McCullough等^[72]的研究表明不添加助剂的情况下,施用8h之后叶片对双草醚的吸收量为25%,添加植物油、非离子表面活性剂和甲基化种子植物油能够使叶片对双草醚的吸收率分别增加20%,21%和50%,因此在使用双草醚时建议和助剂混用。

4.3 狗牙根草坪芽后应用防除案例

狗牙根对多种芽后除草剂具有较强的耐受性,Leon等^[73]研究了氨唑草酮对狗牙根草坪交播黑麦草中一年生早熟禾的防除效果,结果表明在交播黑麦草8~10周以后施用氨唑草酮,能够降低其对黑麦草的伤害,同时也能够有效控制一年生早熟禾。Elmore等^[14]的研究表明硝磺草酮($0.28 \text{ kg}\cdot\text{hm}^{-2}$)和氨唑草酮($0.075 \text{ kg}\cdot\text{hm}^{-2}$)具有协同增效的作用,能够有效控制交播黑麦草狗牙根草坪上的一年生早熟禾。Reed等^[74]的研究表明在狗牙根休眠期施用丙炔氟草胺($0.42 \text{ kg}\cdot\text{hm}^{-2}$)8周以后对一年生早熟禾的防除效果达61%~70%,同时丙炔氟草胺与啶嘧磺隆、草甘膦、草铵膦、戊炔草胺和西玛津混用能够增强防效达80%~90%,同时还能有效控制止血马唐(*Digitaria ischaemum*)的发生。有研究表明丙炔氟草胺在休眠期可安全应用在狗牙根、海滨雀稗、圣奥古斯丁草和结缕草草坪^[75-76]。助剂的使用不会提高丙炔氟草胺的防效,Reed等^[77]的研究表明甲基化植物油、非离子表面活性剂和硫酸铵均不能提高丙炔氟草胺的防效。随着分子育种技术的发展,育种家培育出抗草甘膦的黑麦草品种,因此在交播抗性品种的狗牙根草坪上可以使用草甘膦控制一年生早熟禾^[78]。Carroll等^[79]的研究表明,通过梳草能使狗牙根草坪中一年生早熟禾的数量降低41%~47%,因为垂直切割能够使土壤中的一年生早熟禾种子翻出地面,降低其发芽率。

4.4 海滨雀稗草坪芽后应用防除案例

海滨雀稗对除草剂较为敏感,据统计可用于海滨雀稗草坪上的除草剂约20种^[80],常用于防除海滨雀稗草坪上一年生早熟禾的苗后除草剂主要有氨唑草酮、戊炔草胺、啶嘧磺隆、多效唑。Yu等^[81]的研究表明冬季和春季施用氨唑草酮($0.098\sim 0.392 \text{ kg}\cdot\text{hm}^{-2}$)对海滨雀稗的伤害程度小于5%,高剂量组($0.392 \text{ kg}\cdot\text{hm}^{-2}$)对一年生早熟禾的防除效果为78%~90%,和戊炔草胺($1.68 \text{ kg}\cdot\text{hm}^{-2}$)的防除效果相当。Johnston等^[82]的研究表明在海滨雀稗的休眠期使用氨唑草酮($0.196 \text{ kg}\cdot\text{hm}^{-2}$) + 啶嘧磺隆($0.026 \text{ kg}\cdot\text{hm}^{-2}$)组合对一年生早熟禾的防除效果大于80%,对海滨雀稗的伤害程度为13%~29%。McCullough等^[83]的研究结果表明戊炔草胺在海滨雀稗完全休眠期、50%返青期、100%返青期施用相对安全,最大伤害程度不超过7%,同时6周以后戊炔草胺($0.84, 1.68, 3.36 \text{ kg}\cdot\text{hm}^{-2}$)对一年生早熟禾的防除效果为67%、90%和98%;此外其还研究了其他类型除草剂对海滨雀稗的安全性,结果表明三氟啶磺隆($0.03 \text{ kg}\cdot\text{hm}^{-2}$)、双草醚($0.11 \text{ kg}\cdot\text{hm}^{-2}$)、莠去津($2.24 \text{ kg}\cdot\text{hm}^{-2}$)对海滨雀稗的伤害程度超过20%,甲酰胺基磺隆($0.03 \text{ kg}\cdot\text{hm}^{-2}$)、砒嘧磺隆($0.03 \text{ kg}\cdot\text{hm}^{-2}$)和乙氧呋草磺($1.68 \text{ kg}\cdot\text{hm}^{-2}$)伤害程度为7%~20%。

4.5 结缕草草坪芽后应用防除案例

结缕草对多种芽后除草剂具有较好的耐受性,在生长期可使用 methiozolin、氨基草酮、啶嘧磺隆、三氟啶磺隆和磺酰磺隆等药剂防除一年生早熟禾。在休眠期可使用草甘膦和草铵膦等灭生性除草剂进行点喷处理,均能够有效抑制一年生早熟禾。有研究表明草甘膦+染色剂组合对休眠结缕草草坪中的一年生早熟禾具有较好的防除效果,且不会影响结缕草春季返青^[84]。Craft等^[85]的研究表明在结缕草休眠期施用甲酰胺磺隆、西玛津、丙炔氟草胺+敌草快、丙炔氟草胺+草甘膦、丙炔氟草胺+草铵膦组合均能有效防除一年生早熟禾。除此之外,通过梳草能够使结缕草草坪中的一年生早熟禾种子露出地表,降低其发芽率^[86]。

5 总结与展望

本研究对成坪高尔夫草坪中一年生早熟禾的化学防除研究进展进行了总结,尤其是对登记在不同草坪草上防除一年生早熟禾的化学药剂进行全面梳理,为我国草坪管理者在药剂选择方面提供了帮助。结合目前国内高尔夫球场所用草种和化学药剂登记情况,匍匐剪股颖、高羊茅、肯塔基早熟禾、多年生黑麦草、细羊茅、狗牙根、结缕草和海滨雀稗草坪上防除一年生早熟禾的芽前药剂首选氨基乐灵、二甲戊灵、氨基乐灵+甲磺草胺3种药剂,芽后防除选择 methiozolin、氨基草酮、磺酰磺隆、抗倒酯和多效唑5种药剂。狗牙根和结缕草草坪芽后还可选择三氟啶磺隆、啶嘧磺隆、砒嘧磺隆、甲酰胺基磺隆和西玛津5种药剂来防除一年生早熟禾。长期使用同一作用机制的药剂会导致抗性的产生^[87-88],因此推荐不同作用机理的药剂轮换或组合使用。

一年生早熟禾是高尔夫运动草坪上的重要杂草,对其精准有效防除能够提高草坪的质量,增加草坪的使用年限。目前一年生早熟禾的防除存在重芽后轻芽前问题,出苗后一年生早熟禾生长迅速且易抽穗开花,大大增加了芽后防除难度。一年生早熟禾的防除应遵循“芽前控制为主,芽后茎叶处理为辅”的基本原则,形成主动除草的观念意识。除此之外,芽前除草剂的施用时间也不准确,草坪管理者应该对往年的发芽时间做好记录,一定要在种子萌发之前完成芽前除草剂施用工作。芽前除草剂并不能够抑制所有种子萌发,因此出苗后应该及时进行芽后处理,遵循“除早除小”的原则,在其抽穗开花之前进行茎叶处理防除效果更好。施用除草剂时严格按照推荐剂量,随意增加用量会对草坪草造成伤害。苗期可以采用植物生长调节剂和低剂量芽后除草剂组合来防除一年生早熟禾,这样能够有效降低除草剂对草坪草的伤害。一年生早熟禾的防除是系统长周期的过程,切勿操之过急,同时也可将农业措施和化学措施结合起来进行防控,如打孔、梳草和垂直切割均可降低一年生早熟禾的覆盖度。另外目前已有报道生物型除草剂应用在冷季型草坪上,未来随着生物技术的发展,更多的新型生物除草剂将会被用于一年生早熟禾^[89],使其防除有更多的选择。

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