Integrating New Tools for Grass Weed Control in Kentucky Bluegrass and Perennial Ryegrass

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I. Fall-planted Kentucky Bluegrass and Perennial Ryegrass field trials-2017

Two field trials evaluating herbicide options for annual grass weed control in Kentucky bluegrass and perennial ryegrass (Columbia River Seed) were planted in August; one at the WSU research station in Central Ferry, WA and the WSU research station in Othello, WA. The objectives of these studies were to 1) evaluate the efficacy of indaziflam (Alion), mesotrione (Callisto), and pyroxasulfone (Zidua) for preemergence control of downy brome (*Bromus tectorum L.*), rattail fescue (*Vulpia myuros*), alkali grass (*Puccinellia distans*) and annual bluegrass (*Poa annua*) in turf grasses 2) evaluate the efficacy of soil applications of GA on emergence and stand establishment of cash crop and grass weeds in the seed bank.

Four varieties of Kentucky bluegrass, two elite (Rubix and Diva) and two early maturing varieties (Black Jack and Arc) were planted at Central Ferry, WA. Two elite varieties of Kentucky bluegrass (Diva and Dauntless), and two varieties of perennial ryegrass (Playfast. and Prominent) were planted at Othello, WA. All studies were planted with a Great Plains drill with 10-inch row spacing at 3 lbs seed A^{-1} with two rows for each species. Plots were 10 feet by 30 feet at Central Ferry, and 5 feet by 30 feet at Othello. Soil analyses at both locations indicated seedbeds were a slit loam composition. A total of eighteen preemergence (PRE) herbicide treatments and four GA treatments were evaluated for grass weed control, seedbank emergence, and stand establishment for both cash crop and weeds at both locations (Tables 1-3). Treatments were applied on August 13, 2017 at Central Ferry, WA, and on August 20, 2017 in Othello, WA. A backpack sprayer was used for treatment application at 15 GPA through four 8002 XR flat fan nozzles, and each treatment was replicated 4 times using a complete randomized block design. Plots were sprinkler irrigated every other day for 30 minutes. Fertilizer was applied on October 4, 2017 at Central Ferry, WA; at a rate of 120 lb/A nitrogen, 20 lb/A phosphorus, and 10 lb/A sulfur. The Othello location was fertilized as part of seedbed preparation on August 7, 2017 at a rate of 110 lb/A nitrogen, 20 lb/A phosphorus, and 20.lb/A potassium.

Table 1. Indaziflam treatments to be tested in Kentucky bluegrass and perennial ryegrass seed production.

No.	PRE	Rate	POST (3 lf to 1 tiller)	Rate
1	Nontreated			
2	Indaziflam	0.026 lb ai/A	No POST	
3	Indaziflam	0.026 lb ai/A	Glufosinate + Ethofumesate (Nortron)+ AMS	0.375 lb ai/a + 1 lb ai/a + 3 lb/a
4	Indaziflam	0.026 lb ai/A	Glufosinate + Metribuzin+ AMS	0.375 lb ai/a + 0.14 lb ai/a + 3 lb/a
5	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	No POST	
6	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	Glufosinate + Ethofumesate (Nortron)+ AMS	0.375 lb ai/a + 1 lb ai/a + 3 lb/a
7	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	Glufosinate + Metribuzin+ AMS	0.375 lb ai/a + 0.14 lb ai/a + 3 lb/a
8	Mesotrione +	6 fl oz	Glufosinate+ Metribuzin AMS	0.375 lb ai/a + 0.14 lb ai/a + 3 lb/a
9	Mesotrione	6 fl oz	No POST	

Table 2. Pyroxasulfone herbicide treatments to be tested in Kentucky bluegrass and perennial ryegrass seed production.

No.	PRE	Rate	POST (3 lf to 1 tiller)	Rate
1	Nontreated			
2	Pyroxasulfone + NIS	0.05 lb ai/A+ 0.05% v/v	No POST	
3	Pyroxasulfone + NIS	0.05 lb ai/A+ 0.05% v/v	Glufosinate + Ethofumesate (Nortron) + AMS	0.375 + 1 lb ai/a+ 3 lb/a
4	Pyroxasulfone + NIS	0.05 lb ai/A + 0.05%	Glufosinate + Metribuzin + AMS	0.375 + 0.14 lb ai/a + 3 lb/a
5	Pyroxasulfone + NIS + Mesotrione	0.05 lb ai/A + 0.05% v/v + 6 fl oz	No POST	
6	Pyroxasulfone + NIS + Mesotrione	0.05 lb ai/A + 0.05% v/v + 6 fl oz	Glufosinate + Ethofumesate (Nortron) + AMS	0.375 + 1 lb ai/a + 3 lb/a
7	Pyroxasulfone +	0.026 lb ai/A +	Glufosinate +	0.375 +

	NIS + Mesotrione	0.05% v/v + 6 fl oz	Metribuzin + AMS	0.14 lb ai/a + 3 lb/a
8	Mesotrione +	6 fl oz	Glufosinate+ Metribuzin AMS	0.375 lb ai/a + 0.14 lb ai/a + 3 lb/a
9	Mesotrione	6 fl oz	No POST	

Table 3. GA treatments to be tested in Kentucky bluegrass and perennial ryegrass seed production.

No.	PRE	Rate	POST (3 lf to 1 tiller)	Rate
1	Nontreated			
2	GA	0.05 oz/a	Glufosinate + Metribuzin AMS	0.375 lb ai/a + 0.14 lb ai/a + 3 lb/a
3	GA	1 oz/a	Glufosinate + Metribuzin AMS	0.375 lb ai/a + 0.14 lb ai/a + 3 lb/a
4	GA	5 oz/a	Glufosinate + Metribuzin AMS	0.375 lb ai/a + 0.14 lb ai/a + 3 lb/a
5	GA	50 oz/a	Glufosinate + Metribuzin AMS	0.375 lb ai/a + 0.14 lb ai/a + 3 lb/a
6	No PRE		Glufosinate + Metribuzin AMS	0.375 lb ai/a + 0.14 lb ai/a + 3 lb/a

II. Preliminary Field Trial Results – Fall 2017

All test plots were monitored once a week to capture first emergence, track herbicide injury, and to monitor seedling establishment after initial herbicide and GA treatments at both test locations. Seedling counts were taken on October 25, 2017 at Central Ferry, WA and on October 26, 2017 at Othello, WA to determine stand establishment.

Central Ferry, WA

Emergence: Except for rattail fescue, first weed emergence was observed on September 20, 2017, in all non-treated checks for trials indicated in Tables 1-3. Kentucky bluegrass and perennial ryegrass emergence in the indaziflam and pyroxasulfone trials occurred a week behind the grass weed species. Both indaziflam and pyroxasulfone treatments applied PRE, alone or in combination with mesotrione, prevented the emergence of all planted species on first rating date.

However, mesotrione-only treatments applied PRE, resulted in poor emergence of turf grass, and provided partial control of annual bluegrass and downy brome.

Herbicide Injury and Stand Establishment: Herbicide injury was measured weekly after PRE-emergent herbicide applications. Injury was rated using a scale where 0 = no injury (no control), and 100% = complete injury (death). In all Central Ferry trials there was no observable gradient in seedling injury meaning that seedlings either emerged or they did not, and if they emerged there was no apparent indication of stress, i.e. withered leaf tips, chlorosis, or stunting. Stand establishment was rated 8 weeks after PRE-emergent herbicide treatments (8WAT) and by taking counting seedlings per row. Uniform seedling emergence occurred in all non-treated checks in both indaziflam and pyroxasulfone trials and was comparable between treatment 1; the non-treated check, and treatment 9; POST-emergence application of mesotrione for each species planted. PRE-emergent applications of indaziflam alone or in combination with mesotrione (treatments 2- 7) resulted in partial or complete control of rattail fescue, annual bluegrass, alkali grass, and all varieties of Kentucky bluegrass (Table 4 and Table 5). Treatments also cause reduced emergence of downy brome. Eight weeks after treatment PRE-emergent applications of mesotrione resulted in complete control of Kentucky bluegrass but only partially controlled downy brome, alkali grass, and annual bluegrass.

Table 4. Indaziflam efficacy in annual grass weeds at Central Ferry, WA. Values represent average seedling emergence 8 WAT per 10 ft row, LSD (P = 0.05) and means followed by the same letter do not significantly differ.

No.	PRE	Rate	Downy Brome	Rattail Fescue	Alkali Grass	Annual Bluegrass
1	Nontreated		20 a	10 ab	112.5 a	140 a
2	Indaziflam	0.026 lb ai/A	5 a	0 b	0 a	0 c
3	Indaziflam	0.026 lb ai/A	5 a	0 b	0 a	0 c
4	Indaziflam	0.026 lb ai/A	7.5 a	2.5 b	7.5 a	0 c
5	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	2.5 a	0 b	0 a	0 c
6	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	2.5 a	0 b	0 a	0 c
7	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	5 a	0 b	0 a	0 c
8	Mesotrione	6 fl oz	2.5a	0 b	50 a	112.5 b
9	Mesotrione	6 fl oz	20 a	12.5 a	425.3 a	137.5 a

LSD (P = 0.05)	10.88	6.77	314.47	19.45

Table 5. Indaziflam efficacy in Kentucky bluegrass in Central Ferry, WA. Values represent average seedling emergence 8 WAT per 10 ft row. LSD (P = 0.05) and means followed by the same letter do not significantly differ.

No.	PRE	Rate	Rubix	Diva	Black Jack	Arc
1	Nontreated		27.5 a	27.5 a	40 a	45 a
2	Indaziflam	0.026 lb ai/A	0 b	0 b	0 b	0 b
3	Indaziflam	0.026 lb ai/A	0 b	0 b	0 b	0 b
4	Indaziflam	0.026 lb ai/A	0 b	0 b	0 b	0 b
5	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	0 b	0 b	0 b	0 b
6	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	0 b	0 b	0 b	0 b
7	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	0 b	0 b	0 b	0 b
8	Mesotrione	6 fl oz	0 b	0 b	0 b	0 b
9	Mesotrione	6 fl oz	30 a	25 a	45 a	45 a
LSD (P = 0.05)			6.28	7.36	9.33	17.74

Apart from treatment 5 for downy brome and alkali grass all applications of pyroxasulfone alone or in combination with mesotrione (treatments 2 -7) resulted in complete control of grass weeds and all Kentucky bluegrass varieties (Table 6 and Table 7). As with what was observed in the indaziflam study, PRE applications of mesotrione completely inhibit emergence of Kentucky bluegrass, as well as rattail fescue and alkali grass. However, control over downy brome and annual bluegrass is less effective.

Table 6. Pyroxasulfone efficacy in annual grass weeds at Central Ferry, WA. Values represent average seedling emergence 8WAT per 10 ft row, LSD (P = 0.05) and means followed by the same letter do not significantly differ.

No.	PRE	Rate	Downy Brome	Rattail Fescue	Alkali Grass	Annual Bluegrass
1	Nontreated		45 a	10 b	45 b	67.5 b
2	Pyroxasulfone + NIS	0.05 lb ai/A+ 0.05% v/v	0 c	0 b	0 c	0 d
3	Pyroxasulfone + NIS	0.05 lb ai/A+ 0.05% v/v	0 c	0 b	0 c	0 d

4	Pyroxasulfone + NIS	0.05 lb ai/A + 0.05%	0 c	0 b	0 c	0 d
5	Pyroxasulfone + NIS + Mesotrione	0.05 lb ai/A + 0.05% v/v + 6 fl oz	5 c	0 b	20 c	0 d
6	Pyroxasulfone + NIS + Mesotrione	0.05 lb ai/A + 0.05% v/v + 6 fl oz	0 c	0 b	0 c	0 d
7	Pyroxasulfone + NIS + Mesotrione	0.026 lb ai/A + 0.05% v/v + 6 fl oz	0 c	0 b	0 c	0 d
8	Mesotrione +	6 fl oz	15 b	0 b	0 c	37.5 c
9	Mesotrione	6 fl oz	45 a	17.5 a	112.5 a	87.5 a
LSD (P = 0.05)			9.47	6.28	20.85	11.98

Table 7. Pyroxasulfone efficacy in Kentucky bluegrass weeds at Central Ferry, WA. Values represent average seedling emergence 8WAT per 10 ft row, LSD (P = 0.05) and means followed by the same letter do not significantly differ.

No.	PRE	Rate	Rubix	Diva	Black Jack	Arc
1	Nontreated		47.5 a	47.5 a	90 b	112.5 a
2	Pyroxasulfone + NIS	0.05 lb ai/A+ 0.05% v/v	0 b	15 bc	0 c	30 b
3	Pyroxasulfone + NIS	0.05 lb ai/A+ 0.05% v/v	0 b	0 c	0 c	0 b
4	Pyroxasulfone + NIS	0.05 lb ai/A + 0.05%	0 b	0 c	0 c	0 b
5	Pyroxasulfone + NIS + Mesotrione	0.05 lb ai/A + 0.05% v/v + 6 fl oz	0 b	0 c	0 c	0 b
6	Pyroxasulfone + NIS + Mesotrione	0.05 lb ai/A + 0.05% v/v + 6 fl oz	0 b	0 c	0 c	0 b
7	Pyroxasulfone + NIS + Mesotrione	0.026 lb ai/A + 0.05% v/v + 6 fl oz	0 b	0 c	0 c	0 b
8	Mesotrione +	6 fl oz	0 b	0 c	0 c	0 b
9	Mesotrione	6 fl oz	47.5 a	35 ab	97.5 a	77.5 a
LSD (P = 0.05)			5.11	20.35	4.66	43.26

GA Applications: Previous studies in Anatone, WA and Central Ferry, WA evaluating efficacy of soil application of GA in downy brome suggested that increasing concentration of GA might break seed dormancy, alter emergence timing in the field, and thus provide an effective tool for management prior to planting crops or during a fallow rotation. Increased GA concentrations resulted in increased seedling emergence and establishment in all seeds planted. Interestingly, it appears that there are different degrees of sensitivity to applied GA with downy brome and annual bluegrass responding being the most sensitive, and alkali grass and rattail fescue being the least sensitive (Table 8 and Table 9). It also appears that GA helps with seedling emergence ad establishment in all varieties of Kentucky bluegrass planted, with varying degrees of sensitivity. These results suggest that soil applications may be useful for minimizing the grass weed seed bank prior to planting, and may have some utility in promoting stand establishment in specific varieties of turfgrass. Future work will look to characterize GA response in a dose-dependent manner.

Table 8. Seedling establishment of annual grass weeds in response to soil applied GA at Central Ferry, WA. Values represent average seedling emergence 8WAT per 10 ft row, LSD (P = 0.05) and means followed by the same letter do not significantly differ.

No.	PRE	Rate	Downy Brome	Rattail Fescue	Alkali Grass	Annual Bluegrass
1	Nontreated		101.5 b	82.5 b	18 a	33.8 b
2	GA	0.05 oz/a	172.5 ab	124 b	20.5 a	53.5 b
3	GA	1 oz/a	195.8 a	190.5 a	20.3 a	92.8 a
4	GA	5 oz/a	124 b	116.5 b	30.8 a	98 a
5	GA	50 oz/a	118.3 b	115.5 b	31.3 a	115.8 a
6	No PRE		104 b	111.3 b	17.8 a	38.8 b
LSD (P = 0.05)			49.51	41.79	17.11	33.75

Table 9. Seedling establishment of Kentucky bluegrass in response to soil applied GA at Central Ferry, WA. Values represent average seedling emergence 8WAT per 10 ft row, LSD (P = 0.05) and means followed by the same letter do not significantly differ.

No.	PRE	Rate	Rubix	Diva	Black Jack	Arc
1	Nontreated		23.8 bc	62 ab	46 b	52.8 b
2	GA	0.05 oz/a	2.8 c	43.5 b	39 b	69.5 ab
3	GA	1 oz/a	113.5 a	90.3 a	139 a	77.5 a
4	GA	5 oz/a	113 a	83 a	56.8 b	77.3 a
5	GA	50 oz/a	77.5 ab	94.8 a	112.8 a	69.8 ab

6	No PRE		72 ab	64.3 ab	56.8 b	62 ab
LSD (P = 0.05)			46.41	22.76	42.70	16.08

Othello, WA:

Emergence: Emergence was first observed for weed species on August 21, 2017 in all non-treated checks for trials indicated in Tables 1-3. Unlike what was observed at Central Ferry, after initial PRE-emergent herbicide application, there was no delay in emergence timing in the non-treated checks among weeds (including rattail fescue) or turf species in both the pyroxasulfone trials. However, emergence of alkali grass and annual bluegrass, as well as both Kentucky bluegrass varieties was poor in the non-treated checks suggesting local differences in soil conditions. Total seedling emergence varied among replicates and trials. Both indaziflam and pyroxasulfone treatments applied PRE, alone or in combination with mesotrione, prevented the emergence of all weed species and Kentucky bluegrass varieties planted. Interestingly, perennial ryegrass varieties Playfast and Prominent appeared to show some tolerance to PRE-emergent applications of both indaziflam and pyroxasulfone alone or in combination with mesotrione. Unlike what was observed at the Central Ferry site, PRE-emergent mesotrione applications completely controlled all annual grass weeds as well and Kentucky bluegrass and perennial rye grass.

Herbicide Injury and Stand Establishment: Herbicide injury was measured weekly after PRE-emergent herbicide applications. Injury was rated using a scale where 0 = no injury (control), and 100% = complete injury (death). Consistent with what was observed at Central Ferry, there was no apparent seedling injury with PRE-emergent herbicide application. Seedlings either emerged or they did not.

Stand establishment was rated 8 weeks after PRE-emergent herbicide treatments and was done so by taking seedling counts. Due to poor seedling emergence in the indaziflam trail, all seedling counts were compared with Treatment 9; POST-emergence application of mesotrione (to be applied in the spring). Pre-emergent applications of indaziflam alone or in combination with mesotrione (treatments 2- 8) completely controlled rattail fescue, alkali grass, and annual bluegrass and both varieties of Kentucky Bluegrass (Table 10 and Table 11). Downy brome appeared to be partially controlled in treatments 2, 3, 5, 6, and 8, and control may be confounded

by variation in downy brome seed dormancy. Interestingly, perennial ryegrass varieties Playfast and Prominent appeared tolerated PRE applications of both indaziflam and pyroxasulfone alone or in combination with mesotrione. While both perennial ryegrasse varieties had reduced emergence neither had complete loss of germination, and seedlings that emerged were healthy. Future work research will use greenhouse trials to evaluate tolerance levels in all turfgrass to varying concentrations of indaziflam and mesotrione in varieties planted in the 2017 field locations.

Table 10. Indaziflam efficacy in annual grass weeds at Othello, WA. Values represent average seedling emergence 8 WAT per 5 ft row, LSD (P = 0.05) and means followed by the same letter do not significantly differ.

No.	PRE	Rate	Downy Brome	Rattail Fescue	Alkali Grass	Annual Bluegrass
1	Nontreated		7.5 ab	3.8 b	0 b	0.3 b
2	Indaziflam	0.026 lb ai/A	5 ab	0 b	0 b	0 b
3	Indaziflam	0.026 lb ai/A	0 b	0 b	0 b	0 b
4	Indaziflam	0.026 lb ai/A	8.8 a	0 b	0 b	0 b
5	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	1.3 ab	0 b	0 b	1.3 b
6	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	1.3 ab	0 b	0 b	0.5 b
7	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	7.5 ab	0 b	0 b	0 b
8	Mesotrione	6 fl oz	0 b	0 b	0 b	0 b
9	Mesotrione	6 fl oz	6.3 ab	11.3 a	65 a	43.5 a
LSD (P = 0.05)			5.11	5.78	6.28	14.99

Table 11. Indaziflam efficacy in Kentucky bluegrass and perennial ryegrass at Othello, WA. Values represent average seedling emergence 8 WAT per 5 ft row, LSD (P = 0.05) and means followed by the same letter do not significantly differ.

No.	PRE	Rate	Diva	Dauntless	Prominent	Playfast
1	Nontreated		0 b	0 b	20 b	13.8 b
2	Indaziflam	0.026 lb ai/A	0 b	0 b	12.5 bc	0 b
3	Indaziflam	0.026 lb ai/A	0 b	0 b	5 c	6.3 b
4	Indaziflam	0.026 lb ai/A	13.8 b	0 b	0 c	1.3 b
5	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	0 b	0 b	0 c	22.5 b

6	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	0 b	0 b	0 c	16.3 b
7	Indaziflam + Mesotrione	0.026 lb ai/A + 6 fl oz	0 b	0 b	12.5 bc	7.5 b
8	Mesotrione	6 fl oz	0 b	16.3 b	2.5 c	50 a
9	Mesotrione	6 fl oz	38.8 a	41.3 a	51.3 a	26.3 b
LSD (P = 0.05)			21.52	19.45	10.52	19.19

Uniform seedling emergence occurred in all non-treated checks in the pyroxasulfone trial and was comparable between the non-treated check, and the POST application of mesotrione (to be applied in the spring) for each species planted. Apart from treatment 5, all applications of pyroxasulfone alone or in combination with mesotrione (treatments 2 through 8) resulted in complete control of rattail fescue, alkali grass, annual bluegrass, and both species of the Kentucky bluegrass (Table 12 and Table 13). These treatments also resulted a significant reduction in the number of established downy brome seedlings, as well as both perennial ryegrass species, suggesting a degree of herbicide tolerance in these species. Greenhouse trials will be established to evaluate turfgrass tolerance to pyroxasulfone alone or with mesotrione.

Table 12. Pyroxasulfone efficacy in annual grass weeds at Othello, WA. Values represent average seedling emergence 8WAT per 5 ft row, LSD (P = 0.05) and means followed by the same letter do not significantly differ.

No.	PRE	Rate	Downy Brome	Rattail Fescue	Alkali Grass	Annual Bluegrass
1	Nontreated		22.5 ab	2.5 ab	42.5 b	33.8 c
2	Pyroxasulfone + NIS	0.05 lb ai/A+ 0.05% v/v	3.8 c	0 b	0 c	0 d
3	Pyroxasulfone + NIS	0.05 lb ai/A+ 0.05% v/v	0 c	0 b	0 c	0 d
4	Pyroxasulfone + NIS	0.05 lb ai/A + 0.05%	3.8 c	0 b	0 c	0 d
5	Pyroxasulfone + NIS + Mesotrione	0.05 lb ai/A + 0.05% v/v + 6 fl oz	16.3 abc	6.3 a	42.5 b	42.5 b
6	Pyroxasulfone + NIS + Mesotrione	0.05 lb ai/A + 0.05% v/v + 6 fl oz	10 bc	0 b	0 c	0 d
7	Pyroxasulfone + NIS + Mesotrione	0.026 lb ai/A + 0.05% v/v + 6 fl oz	2.5 c	0 b	0 c	0 d

8	Mesotrione +	6 fl oz	0 c	0 b	0 c	0 d
9	Mesotrione	6 fl oz	25 a	2.5 ab	56.3 a	57.5 a
LSD (P = 0.05)			10.99	3.65	5.39	4.33

Table 13. Pyroxasulfone efficacy in Kentucky bluegrass and perennial ryegrass weeds at Othello, WA. Values represent average seedling emergence 8WAT per 5 ft row, LSD (P = 0.05) and means followed by the same letter do not significantly differ.

No.	PRE	Rate	Diva	Dauntless	Prominent	Playfast
1	Nontreated		23.ab	23.8 a	33.8 b	61.3 a
2	Pyroxasulfone + NIS	0.05 lb ai/A+ 0.05% v/v	0 b	0 c	5 c	7.5 b
3	Pyroxasulfone + NIS	0.05 lb ai/A+ 0.05% v/v	0 b	0 c	3.8 c	0 b
4	Pyroxasulfone + NIS	0.05 lb ai/A + 0.05%	5 b	0 c	0 c	17.5 b
5	Pyroxasulfone + NIS + Mesotrione	0.05 lb ai/A + 0.05% v/v + 6 fl oz	15 ab	7.5 b	68.8 a	50 a
6	Pyroxasulfone + NIS + Mesotrione	0.05 lb ai/A + 0.05% v/v + 6 fl oz	0 b	0 c	0 c	0 b
7	Pyroxasulfone + NIS + Mesotrione	0.026 lb ai/A + 0.05% v/v + 6 fl oz	0 b	0 c	0 c	0 b
8	Mesotrione +	6 fl oz	21.3 ab	0 c	0 c	0 b
9	Mesotrione	6 fl oz	38.8 a	26.3 a	58.8 a	51.3 a
LSD (P = 0.05)			21.35	4.20	16.05	15.58

GA applications: Uniform seedling emergence occurred in all non-treated checks, and densities were comparable with POST-emergent application of Glufosinate (to be applied in the spring). Increasing applications of GA resulted in increased seedling emergence in downy brome, alkali grass, and annual bluegrass, but had no effect on rattail fescue (Table 14 and Table 15). GA applications Interestingly, the lowest GA applications (treatment 2) resulted in increased seedling establishment for both Kentucky Bluegrass varieties but did not increase seedling establishment in either perennial ryegrass varieties. These results suggest that soil applications may be useful for minimizing the grass weed seed bank prior to planting, and may have some utility in

promoting stand establishment in turfgrass. Future work will look to characterize GA response in a dose-dependent manner.

Table 14. Seedling establishment of annual grass weeds in response to soil applied GA at Othello, WA. Values represent average seedling emergence 8WAT per 10 ft row, LSD (P = 0.05) and means followed by the same letter do not significantly differ.

No.	PRE	Rate	Downy Brome	Rattail Fescue	Alkali Grass	Annual Bluegrass
1	Nontreated		15 c	10 a	50 b	35 ab
2	GA	0.05 oz/a	33.8 ab	8.8 a	68.8 a	57.5 a
3	GA	1 oz/a	42.5 a	7.5 a	65 a	33.8 ab
4	GA	5 oz/a	18.8 bc	11.3 a	61.3 ab	53.8 a
5	GA	50 oz/a	13.8 c	3.8 a	76.3 a	43.8 ab
6	No PRE		20 bc	1.3 a	48.8 b	20 b
LSD (P = 0.05)			13.35	14.88	11.12	19.47

Table 15. Seedling establishment of Kentucky bluegrass in response to soil applied GA at Othello, WA. Values represent average seedling emergence 8WAT per 5 ft row, LSD (P = 0.05) and means followed by the same letter do not significantly differ.

No.	PRE	Rate	Diva	Dauntless	Prominent	Playfast
1	Nontreated		35 ab	21.3 cd	60 ab	71.3 a
2	GA	0.05 oz/a	57.5 a	52.5 a	71.3 a	71.3 a
3	GA	1 oz/a	33.8 ab	10 d	33.8 c	53.8 a
4	GA	5 oz/a	53.8 a	32.5 bc	62.5 ab	32.5 a
5	GA	50 oz/a	43.8 ab	43.8 ab	72.5 a	37.5 a
6	No PRE		20 b	38.8 ab	41.3 bc	51.3 a
LSD (P = 0.05)			19.47	14.13	19.98	30.17

Outcomes and Future Directions:

Indaziflam and pyroxasulfone, applied PRE, have potential for partial to complete control of annual grass weed management in turfgrass production systems. However, due to the apparent sensitivity of both Kentucky bluegrass and perennial ryegrass varieties tested, it will be essential to look at ways of mitigating the harmful effects of herbicides to the cash crop. One of the strategies we will investigate in the second year of this study is the efficacy of carbon-seeding on turf grass survival in combination with PRE applications of indaziflam and pyroxasulfone. PRE applications of mesotrione had variable success in grass weed control and negatively impacted

emergence and establishment of the Kentucky bluegrasses tested. However, two perennial ryegrasses tested appeared to show some tolerance to indaziflam, pyroxasulfone, and mesotrione applications. Tolerance will be explored more directly through a series of greenhouse studies investigating response to herbicide applications in a dose-dependent manner. Finally, it appears that all grass species tested responded to soil applications of GA. This result is important because it suggests that GA applications may be a useful was for minimizing seedbank load prior to a new planting year, and that GA may be an effective tool for helping with crop stand establishment after planting.