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Final Comprehensive Project Report

Collaborative Research and Development Agreement

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Stimulating Germination and Emergence of Wild Oat (*Avena fatua*), Volunteer Oat (*Avena sativa*), Barley (*Hordeum vulgare*), and Wheat (*Triticum aestivum*) with Pyroligneous Acid and Potassium Nitrate

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Project funding collaborators:

The Saskatchewan Wheat Development Commission, the Saskatchewan Oat Development Commission, and the Manitoba Crop Alliance.

a) **Abstract/Summary** - *Maximum of one page. This must include project objectives, results, and conclusions.*

Wild oat is a widespread threat to spring annual crop production on the Canadian Prairies. Multiple herbicide-resistant wild oat biotypes have been identified with resistance towards Groups 1, 2, and 8 chemistry. Infesting populations are difficult to manage due to complex dormancy, a long emergence window, a long-persisting seedbank, and seed shatter corresponding to typical crop harvest timings. Management strategies for targeting the seedbank are limited. Wild oat has previously demonstrated a positive germination response to seedbank or seed treatments of potassium nitrate and gibberellins. Understanding the efficacy of stimulants for wild oat and volunteer cereal emergence at more desirable times such as pre-seeding to utilize broad-spectrum herbicides or post-harvest to utilize a killing frost. The study objective was to evaluate the suitability of applying potassium nitrate and pyroligneous acid for promoting germination and emergence of wild oat and volunteer wheat, barley, and oats. Dose response and interaction experiments were conducted in control environments. The wild oat biotype used was insensitive to nitrogen towards emergence. Pyroligneous acid when used in petri dishes induced dormancy from 5 to 100% solutions. Experiments indicate dormancy signaling reduces in solutions between 1 and 5% PA in petri dishes. Wild oat emergence rate index was increased, indicating significant increases in emergence velocity, for 50 and 100% solutions applied at 200 L ha^{-1}. Volunteer cereals were largely tolerant but were not stimulated by PA when applied from 5 to 100% solutions at 200 L ha^{-1}. Barley emergence was stimulated by 1% PA. This research demonstrates a novel use pattern for stimulating wild oat emergence by applying pyroligneous acid solutions of 50 to 100% at 200 L ha^{-1}, which can be achieved in the field using conventional spray equipment. This research focused on influencing the after-ripening period of endodormancy of wild oat. Other environmental stimuli do influence wild oat dormancy including light and cold temperatures so additional research is required to better understand how seedbank stimulants influence other aspects of dormancy. Additional research is required to evaluate the field efficacy of PA on wild oat and subsequent influence on non-target organisms such as other plants, the microbiome, pathogens, and insects. Applying ≥50% pyroligneous acid solutions may also provide additional herbicidal activity when applied to emerged target species since acetic acid is a major component of pyroligneous acid.

b) **Introduction** – *Brief project background, rationale and objectives.*

Wild oat (*Avena fatua* L.) is a longstanding threat to crop production on the Canadian Prairies. Wild oat is a strong competitor and can induce substantial yield loss when emerging prior to barley (O'Donovan et al., 1985) and at high densities (Bell and Nalewaja, 1968). In early quantitative surveys, wild oat ranked second by relative abundance within the Saskatchewan weed community (Thomas, 1976; Thomas and Wise, 1983). In the latest prairie weed surveys, wild oat ranked second in Saskatchewan (Leeson, 2016), fourth in Manitoba (Leeson et al., 2017), and fifth in Alberta (Leeson et al., 2019). It's dominant place in the weed community is likely a consequence of seed dormancy, competitiveness, and herbicide resistance evolution.

Wild oats have developed resistance to WSSA Group 1 chemistry (Heap et al., 1993). Half of the 1999 surveyed fields in Saskatchewan contained a resistant biotype where 18% of the resistant populations also resisted Group 2 chemistry (Beckie et al., 1999). The authors also reported 6 biotypes of Group 8 resistant wild oat in Saskatchewan and Manitoba in 1997, several of which demonstrated multiple herbicide resistance (Group 1, 2, 8, and 25) (Beckie et al., 1999). Resistance has spread, where 69% of sampled wild oat populations demonstrated herbicide resistance in Alberta (Beckie et al., 2019), 80% for Manitoba (Beckie et al., 2018), and 65% for Saskatchewan (Beckie et al., 2017) for the last round of herbicide resistance surveys on the Prairies. The development of herbicide resistance in wild oats results in additional herbicide inputs and costs atop of standard practices to control wild oat.

Herbicides are an important tool for wild oat management but resistance threatens the longevity of the remaining available tools. Herbicide resistance in wild oat has evolved against several Group 1 herbicides (Heap et al., 1993). Circa 2001 to 2003 on the Prairies, 11% of surveyed fields on the Prairie's contained 1-HR wild oat while 6% contained Group 2 resistance and 16 populations demonstrating multiple herbicide-resistance to Groups 1 and 2 (Beckie et al., 2008). Two, 5-way resistant populations have been identified towards Groups 1, 2, 8 (triallate), 14 (sulfentrazone), and 15 (pyroxasulfone) (Mangin et al., 2016). The authors suggest that previously resistance to Group 1 and 2 (ACCase mutation and enhanced metabolism) and group 8 (enhanced endogenous gibberellins) could limit efficacy of alternative modes of action to control wild oat. Alternative management strategies are needed to help deplete the soil seedbank and reduce the risk of resistance evolution against additional modes of action (Norsworthy et al., 2012).

Physical strategies are limited since no-till systems were adopted on the Canadian Prairies, eliminating tillage as a standard control tool (Awada et al., 2016). Harvest weed seed control has demonstrated that 99% of wild oat seeds can be devitalized using the Harrington Seed Destructor (Tidemann et al., 2017a). Given that wild oat seed shatter occurs as wheat (*Triticum aestivum*) is ripening (Shirtliffe et al., 2000), the opportunity for selecting for earlier-maturing biotypes is possible which would limit a seed destructor's role in integrated weed management.

While dormancy definitions vary, here dormancy will be defined per Lang et al. (1987) as "… the temporary suspension of visible growth of any plant structure containing a meristem" and categorized as either ecodormancy, paradormancy, or endodormancy. Ecodormancy is regulated by environmental factors such as temperature extremes or water stress, paradormancy is regulated by physiological factors outside the impacted structure such as apical dominance, while endodormancy is regulated by physiological factors inside the structure such as chilling and photoperiodic responses (Lang et al., 1987). Potential paradormancy has been shown in wild oat seeds as a result of an ecodormancy response of the mother plant to water stress during seed development (Sawhney and Naylor, 1982). After-ripening is a form of endodormancy (Lang et al., 1987) generally induced after seed formation and is controlled by three genes (Jana et al., 1979) which results in large differences in endodormancy within and between populations (Naylor and Jana, 1976).

Wild oats also demonstrates complex dormancy, to which the degree of endodormancy (after-ripening) is controlled by three genes (Jana et al., 1979) and influenced by the environmental conditions during seed formation (Naylor and Jana, 1976). The resultant field emergence window is typically large, observed from early May to late June in MN and ND (Martinson et al., 2007). While later emerging cohorts may not be as competitive, they still typically produce viable seed which can return to the seedbank and allow an infestation to persist. With escalating concerns regarding glyphosate from consumers, legal cases, environmental and human health push-

back, as well as subsequent impacts on trade, farming without glyphosate may be an eventuality in the near future (Beckie et al., 2020).

Due to wild oat seed demonstrating complex dormancy requirements, the soil seedbank has been identified as the most impactful life-cycle stage for long-term management (Tidemann et al., 2016). If wild oat seed could be stimulated to germinate from the seedbank, overall infestation levels and herbicide input costs to management herbicide-resistant biotypes could be reduced. While efficacy and interaction for field-targeted stimulant sprays requires further study, potential success could impact management decisions for several years as populations rebound to economic thresholds, reducing herbicide inputs and costs. Dormancy release and subsequent germination of wild oat seeds has been demonstrated through scarification, exogenous gibberellic acid (Naylor and Jana, 1976), ethelphon, nitrates (Saini et al., 1986), and liquid smoke (Adkins and Peters, 2001). Two use-patterns for stimulant sprays could be pre-seeding to utilize a broadspectrum burn-down, and a fall, post-harvest spray to utilize a cold temperatures and frost to kill emerged wild oat seedlings.

Reducing the seedbank and subsequent emerging weeds reducing selection pressure on post-emergence herbicides and may reduce reliance on chemical control in-crop or through residual herbicides. Prevention of herbicide resistance requires a comprehensive, diversified, and perennial management strategy which aims to reduce weed populations over time to reduce dependency on chemical inputs (Norsworthy et al., 2012). Stimulating the seedbank is not a new consideration, with recent work using fluridone (Tidemann et al., 2017b), but additional research is required to evaluate efficacy of products for stimulating the soil seedbank.

Wood smoke or pyroligneous acid is an interesting option given that the boreal transition zone, where wild oat ranks highly in the weed community, has historically seen many fires as the natural landscape was settled and converted into agroecosystems (Hobson et al., 2002; Weir and Johnson, 1998). Potassium nitrate is common fertilizer input and has wide source availability to farmers. Fertilizer is an important management input so producers already have the technology and experience in its application. Given that cereals are heavily produced on the Canadian Prairies and that wild oat has historically been a threat to these crops, the impacts on volunteer populations will be evaluated as well. The study objective was to evaluate the dose response and interaction of pyroligneous acid with potassium nitrate for stimulating germination and emergence of wild oat and volunteer wheat, barley, and oats in controlled environments.

c) **Methods –** *Include approaches, experimental design, methodology, materials, sites, etc. Major changes from original plan should be indicated and the reason(s) for the change should be specified.*

Seed stock for all experiments were propagated at the Saskatoon Research and Development Centre (SRDC) research farm greenhouse (52.15° N, 106.58° W). Experiments were conducted at the SRDC (52.14° N, 106.63° W) in Saskatoon, SK. Plants were harvested, transported to the SRDC and threshed, then trials were initiated. Cereals were included to test treatment efficacy on volunteer cereals, plant ecology and physiology similarities with wild oat, and production suitability in wild oat's range on the Canadian Prairies. All experiments were conducted with freshly produced seed to emulate the post-harvest environment and ensure wild oat after-ripening associated endodormancy was present.

All germination tests were conducted in petri dishes (Fisherbrand™ 431760, Thermo Fisher Scientific, Waltham, MA) while emergence tests were conducted in 6 cm square pots. For Petri dishes, seed (25 seeds dish^{-1}) were placed on two pieces filter paper (9-cm diameter, Fisherbrand™ 097902C, Thermo Fisher Scientific), 10 mL of wetting solution were applied, the dish was sealed with Parafilm (Bemis Company, Inc., Neenah WI), and dishes were moved into an incubator for the remainder of the experiment. The wetting solutions were treatment combinations described below for petri dish dose response experiments and mixtures for the interaction experiments. All experiments were conducted in incubators (Conviron Canada, Winnipeg, MB) with a 15/10 C, 12-h day / night cycle.

Emergence tests were conducted in the same controlled environment as the germination tests. Pots were filled with bulk potting soil. Potting soil was a mixture of 208 L of Pro-Mix BX (Premier Tech Horticulture Inc.,

Rivière-du-Loup, QC, Canada), 15 g of Dissolvine chelated iron (13% EDTA) (Nouryon, Amsterdam, Netherlands), 2.0 kg of calcium carbonate derived from ground limestone (Graymont Limited, Richmond BC), 400 g of Evergro superphosphate (0-45-0) (Nutrien Solutions, Calgary, AB), and 7g of zinc (14% Zinc Chelate) (Plant Products Co. Lt., Leamington ON). Seed (25 pot^{-1}) was either buried 1 cm in field soil (Orthic Dark Brown) or deposited on the potting soil surface. Field soil was collected from SRDC research farm. Pots were sprayed with experimental treatments using a custom track sprayer with an application volume of 200 L ha^{-1} with the exception of the potassium nitrate in the interaction experiments due to the high dose. This application system and volume was selected as an initial undertaking with consideration to existing herbicide sprayers available to Saskatchewan producers and as a typical application volume for herbicides. Pots were left in a ventilated room to dissipate any volatile compounds then returned to the incubator approximately 16 hours after application.

Stage 1: Dose Response Experiments. Dose response experiments were conducted to evaluate the impact of potassium nitrate (KNO3) and pyroligneous acid (PA) as stimulants on the germination and emergence of wild oat (HR13-153), oat (AC Morgan), barley (CDC Copeland), and wheat (CDC Brandon). Cereal cultivar selection was based on availability at Plant Genome Resource Canada with consideration for reported acreage to the Saskatchewan Crop Insurance Corporation. A resistant wild oat biotype (HR13-153) maintained at SRDC was used, which originated from a producer field within Saskatchewan.

Each species were propagated in the greenhouse at the SRDC research farm greenhouse (52.15° N, 106.58° W) until maturity (Table 1). A total of sixteen unique dose response experiments were conducted on freshly produced seed, with each experiment repeated (Table 2). Experiments were conducted on each species separately but all trials were conducted near-simultaneously to permit comparisons. Dose response for PA used a commercially available product (Sigma-Aldrich, MilliporeSigma Canada Lt. Oakville ON) and evaluated varying concentrations (0, 5, 10, 20, 50, and 100%). Dose response experiments for KNO3 (VWR International, Radnor, PA) evaluated five concentrations: 0, 0.1, 1, 10, and 100 mM solutions.

Table 1. Planting, flowering, and harvest dates for phase one of seed stimulation experiments on wild oat (*Avena fatua* 'HR13-153'), oats (*Avena sativa* 'AC Morgan'), barley (*Hordeum vulgare* CDC Copeland), and wheat (*Triticum aestivum* 'AAC Brandon') in Saskatoon, SK in 2021.

Species	Run	Planting Date	Flowering Date	Harvest Date
Wild oat	1	April 08	May 25	July 13
Oat	1	April 08	May 31	July 13
Barley	1	April 08	June 07	July 12
Wheat	1	April 08	May 21	July 12
Wild oat	2	May 07	June 24	August 13
Oat	2	May 07	June 17	August 12
Barley	2	May 07	July 8	August 12
Wheat	2	May 07	June 17	August 12

Table 2. Trial initiation start dates for potassium nitrate and pyroligneous acid dose response work in Saskatoon, SK in 2021.[1]

	Potassium nitrate dose response				Pyroligneous acid dose response			
Species	Petri dish		Potted		Petri dish		Potted	
	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2
Wild oat	July 15	Aug. 27	July 16	Aug. 27	July 22	Aug. 30	July 22	Aug. 30
Oat	July 15	Aug. 27	July 16	Aug. 27	July 22	Aug. 30	July 21	Aug. 30

Barley	July 15	Aug. 27	July 13	Aug. 27	July 22	Aug. 30	July 21	Aug. 30
Wheat	July 12	Aug. 27	July 13	Aug. 27	July 22	Aug. 30	July 21	Aug. 30

[1] Germination and emergence trials were conducted in an incubator (under a 12-h, 15/10 C day/night cycle). Cultivars are identified in Table 1.

Stage Two: Stimulant Interaction Experiments. The influence PA and KNO3 combinations on wild oat and cereal seed stimulation was evaluated in both pots and petri dishes in controlled environments in Saskatoon, SK in 2021. This experiment was initially to select the best treatments from the dose response on wild oat GRI and ERI. Unfortunately, there was no substantial dose response by either product, so lower doses of PA were evaluated for their effect and interaction in Petri dishes with a higher dose of KNO3 chosen due to previous research (Agenbag and de Villiers, 1989). Utilizing lower doses would help understand the inhibitory influence of PA in petri dishes to determine where inhibition is lost, as well as influence on cereals at lower doses when sprayed.

The experimental design for germination experiments was a two-factor factorial arranged as a randomized complete block with four blocks. Each species was its own experiment but all experiments were conducted simultaneously in the same incubator. The first factor was KNO3 applied at either 0 or 125 kg N ha^{-1}. The second factor was PA dose at 0, 0.1, 1, and 10% solutions. The experimental design for emergence experiments was a three-factor factorial, arranged as a randomized complete block. The first factor was burial depth, the second factor was KNO3 application (o or 125 kg N ha^{-1}), and the third factor was PA dose (0, 0.1, 1, and 10% solutions).

Details regarding seed propagation are found in Table 3. The initiation dates for both experimental runs are found in Table 4. The wild oat variety remained the same due to previous testing but the cereal cultivars changed based on availability at the Saskatoon RDC farm.

Table 3. Planting, flowering, and harvest dates for phase two of seed stimulation experiments on wild oat (*Avena fatua* 'HR13-153'), oats (*Avena sativa* 'AC Morgan'), barley (*Hordeum vulgare* 'CDC Austenson'), and wheat (*Triticum aestivum* 'CDC Stanley') in Saskatoon, SK in 2021.

Species	Run	Planting Date	Flowering Date	Harvest Date
Wild oat	1	June 8	July 19	Oct. 4
Oat	1	June 8	July 31	Oct. 4
Barley	1	June 8	Aug. 11	Oct. 8
Wheat	1	June 8	July 19	Oct. 8
Wild oat	2	July 19	Sept. 13	Nov. 18
Oat	2	July 19	Sept 22	Nov. 18
Barley	2	July 19	Oct. 6	Nov. 18
Wheat	2	July 19	Sept. 13	Nov. 18

Table 4. Trial initiation start dates for potassium nitrate and pyroligneous acid interaction experiments in Saskatoon, SK in 2021.[1]

	Potassium nitrate dose response			
Species	Petri dish		Potted	
	Run 1	Run 2	Run 1	Run 2
Wild oat	Oct. 8	Dec. 2	Oct. 8	Dec. 2
Oat	Oct. 8	Dec. 2	Oct. 8	Dec. 2
Barley	Oct. 22	Dec. 8	Oct. 22	Dec. 8
Wheat	Oct. 22	Dec. 8	Oct. 22	Dec. 8

[1] Germination and emergence trials were conducted in an incubator (under a 12-h, 15/10 C day/night cycle). Cultivars are identified in Table 3.

For application of KNO3 to pots, the material was deposited as a solid to the potting soil or field soil surface due to concerns with solubility and spraying. This dose was chosen since no positive dose response found at the concentrations tested for KNO3 in Phase 1, so a higher dose was chosen from the literature to evaluate the stimulatory or inhibitory impact (Agenbag and de Villiers, 1989) and interaction with PA.

Data Collection and Analysis. Seed germination or seedling emergence was monitored for four weeks, typically five times per week for wheat and barley and bi-weekly for oat and wild oat. For germination experiments, a seed was considered germinated if the radical was protruding the seed coat. For emergence experiments, the presence of the cotyledon above the soil surface was used to indicate emergence. Cumulative germination or emergence was calculated and expressed as a percentage of the 25 seeds per experimental unit. The germination rate was expressed using the germination rate index (GRI), as previously employed on wild oat (Sharma et al., 1976):

$$GRI = \frac{G_1}{T_1} + \frac{G_2}{T_2} + \cdots + \frac{G_n}{T_n} \quad (1)$$

where, G_1 = % germination for the first count (T_1); G_2 = additional % germination at second count (T_2); G_n = additional % germination at the final count (T_n); T_1 = the days from planting until the first count, T2 = the days from planting until the second count; and Tn = the days from planting until final count. Similarly, this metric was used to evaluate increases in emergence rate in response to stimulants, modified as the emergence rate index (ERI), substituting % emergence for % germination in equation 1.

Data analysis was conducted in SAS (9.04, SAS Institute Inc., Cary, NS, USA). An analysis of variance was conducted first according to the experimental design using the GLIMMIX procedure. Experiment runs were also considered as factors for the analysis in order to verify assumptions and detect any differences between runs. For Phase 1, the experimental design for the petri dish experiments were randomized complete blocks while the potted experiments were a two-factor factorial, arranged as a randomized complete block. Block was considered a random effect, specifying the compound symmetry covariance structure. If the dose response factor was significant, the structure of that response was characterized using regression in SigmaPlot (Build 14.5.0.101. Systat Software, Inc., San Jose, CA). Graphs were also constructed using SigmaPlot. If the burial factor or interaction factors were significant, means comparison was conducted using Tukey's honest significance difference by using the LSMEANS statement of PROC GLIMMIX, specifying the Tukey's adjustment. Assumptions of normality and constant variance were verified using residual plots produced using the "plots=studentpanel" option of PROC GLIMMIX.

d) **Results** – *Present and discuss project results, including data, graphs, models, maps, design and technology development.*

Stage 1: Dose Response Experiments. Comparatively between species across the experiments, wild oat and oat had similar germination and emergence characteristics, including lower GRI and a longer germination or emergence window to observe. Wheat and barley typically emerged much more rapidly and the window of observation was typically quite less, only 3 or 4 days. Their comparative germination rate index during Phase 1 is shown in Figure 1.

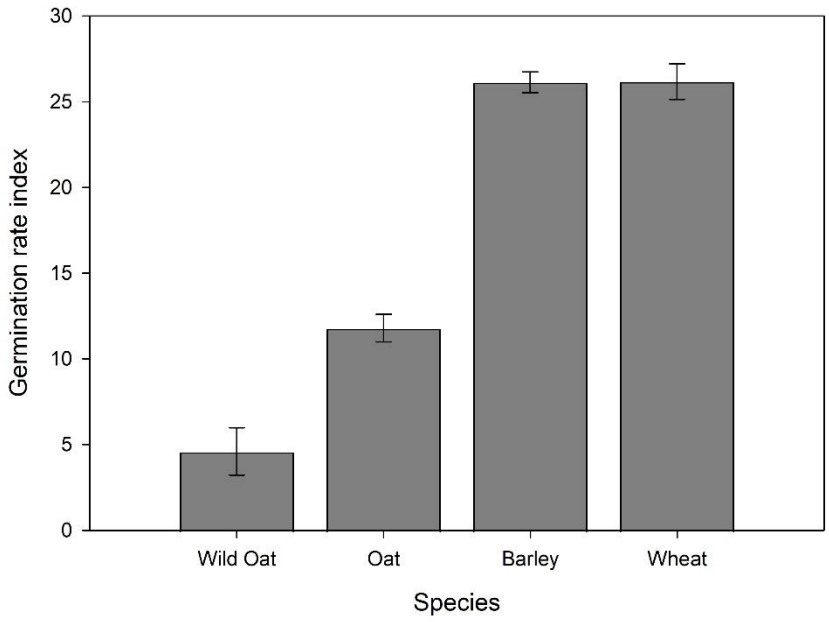

Figure 1. Mean germination rate index (n=8) of freshly produced seed of wild oat (*Avena fatua*), oat (*Avena sativa*), barley (*Hordeum vulgare*), and wheat (*Triticum aestivum*) in the non-treated control petri dishes in an incubator for the pyroligneous acid dose response experiments conducted in Saskatoon, SK.

KNO3 Germination. For wild oat, there was no impact of KNO3 dose (p=0.8083), cycle (0.4800), or an interaction between cycle and dose (p=0.3599). For oats, there was an impact of cycle (p=0.0055) but no impact of dose (p=0.2128) nor a cycle by dose interaction (p=0.8819). The difference between cycles was characterized by a higher GRI (11.93) in the first experiment run compared to the second cycle (8.25). For barley assumptions could not be satisfied so cycles were analyzed separately. For the first run, there was no impact of KNO3 dose (p=0.0718). For the second cycle, there was an impact of KNO3 dose (p=0.0011). There was no stimulatory effect of KNO3 impact on barley germination model but there was a reduction in GRI with 100 mM solution used to wet the petri dishes. The GRI was 28 for the 0, 0.1, and 1 mM solutions, which was similar to the 26 GRI of the 10 mM solution, and all were different from the 21 GRI of the 100 mM solution using Tukey's test.

For wheat, there was no impact of cycle (0.2564) but there was an impact of KNO3 dose (p<0.0001).This dose response was similar to barley in cycle 2 and largely linear, with no stimulation observed and inhibition of GRI at 100 mM (Table 5).

Table 5. Impact of potassium nitrate on the germination rate index for barley (*Hordeum vulgare*) (experimental run 2) and wheat (*Triticum aestivum*) (both experimental runs) within petri dishes in incubators in Saskatoon, SK, in 2021.

Potassium nitrate dose	Germination rate index.		
	Barley	Wheat 1	Wheat 2
0	28 a	26 a	26 a
0.1	28 a	22 bc	24 ab
1	28 a	26 a	26 a
10	26 a	27 a	24 ab

100	21	b	19	c	22	bc	

PA Germination. Assumptions of constant variance and normality could not be satisfied for the PA dose response data for each of the test species. This was due to the dataset being zero-laden as to PA induced dormancy in all species with one exception. This exception was very minor germination by oat in the second run (GRI = 0.4). Seeds within PA treatments were typically imbibed but had not germinated, indicating induced dormancy in response to their environment, since moisture itself was not limiting. The induction of dormancy in this setting is likely due to the stable smoke signal persisting in the petri dishes.

KNO3 Emergence. For wild oat, there was no impact of KNO3 dose (p=0.3897), burial (p=0.2920), nor an interaction between dose and burial (p=0.2164). There was an impact of experimental run (p=0.0134) but there no was no interaction between cycle and dose (p=0.8427), cycle by burial (p=0.3708), nor a three way interaction (p=0.2987). The second cycle demonstrated a consistently higher ERI (6.3) compared to the first (5.8).

For oats, there was no impact of KNO3 dose (p=0.6828), burial (0.4783), nor interaction between KNO3 dose and burial (p=0.3327) on oat emergence. There was an impact of cycle (p=0.0002) and an interaction between cycle and burial (p=0.0002) but no interaction between cycle and dose (p=0.7687). The interaction is characterized by a higher ERI for oat seed deposited on the surface in the first experimental run (Table 6). While the amount of dead seed wasn't estimated for emergence trials, these results are consistent with the KNO3 dose response on seed germination.

Table 6: Oat (*Avena sativa*) and wheat (*Triticum aestivum*) emergence influenced by burial for both experimental runs of the potassium nitrate dose response experiments conducted in incubators in Saskatoon, SK, in 2021.

Cycle	Burial	Emergence rate index			
		Wheat		Oat	
1	0	7.436	A	15.28	A
2	0	4.1997	B	13.97	B
1	1	5.509	B	12.59	C
2	1	5.5512	B	9.45	D

For barley, there was an impact of experimental cycle (p<0.0001) and burial depth (p<0.0001) but no impact of KNO3 dose (p=0.3937), a dose by burial interaction (p=0.4292), a cycle by dose interaction (p=0.9281), a cycle by burial interaction (p=0.1376), or a three way interaction between cycle, dose, and burial (p=0.5065). The first cycle demonstrated a significantly higher GRI (15.74) compared to the second cycle (12.56). The ERI was higher for the surface-deposited seed (15.85) compared to burial at 1 cm (12.46).

For wheat, there was an impact of cycle (p<0.0001), burial (p<0.0001), and a burial by cycle interaction (p=0.0010) but no impact of KNO3 dose (p=0.7998), a dose by burial interaction (p=0.1725), a cycle by dose interaction (p=0.3624), nor a three way interaction between cycle, dose, and burial (p=0.1828). The interaction was characterized by increased ERI for first experimental run compared to other depths and cycles (Table 6).

Overall, across the four species, KNO3 typically did not promote an increased ERI when applied at the tested concentrations. Some changes in the ERI were detected between runs for various species. This could be an influence of material environment during propagation, which has been demonstrated in wild oat (Sawhney and Naylor, 1982).

PA Emergence. The assumption of constant variance could not be satisfied due to structure in the residual/predicted value plot so species were analyzed separately.For wild oat, there was an impact of cycle (p<0.01), PA dose (P=0.05), and a cycle by burial interaction (p<0.01) on the ERI of wild oat. There was no impact of

burial (p=0.45), a burial and dose interaction (p=0.58), cycle by dose (p=0.29), and the three way interaction (p=0.19). The dose response of PA is shown in Figure 2. Confirmative t-tests (α=0.05) were conducted on the 50 and 100% doses to confirm a difference from the control. This is a promising result given that the velocity of emergence for wild oat during the after-ripening period can be enhanced by spraying PA at 50 or 100% solutions at 200 L ha^{-1}. The interaction between cycle and burial depth is characterized by differences between experimental runs across the two depths (Table 7).

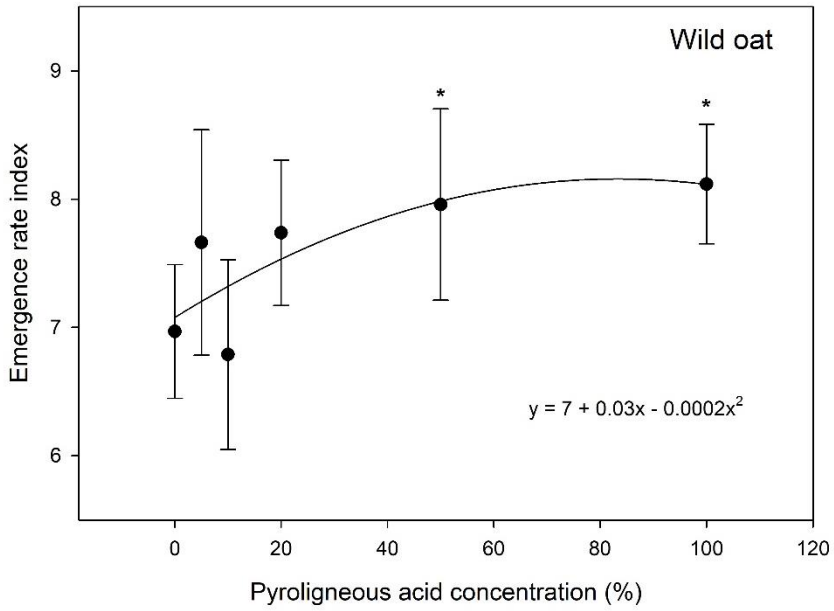

Figure 2: Wild oat (*Avena fatua*) emergence rate index response to increasing concentrations of pyroligneous acid applied at 200 L ha^{-1}. Error bars represent the standard error of the mean. Values are an average of both the 0 and 1 cm seeding depth. An asterisks indicates a significant difference between the treatment and the control for confirmation purposes using a t-test (α=0.05).

Table 7: Interaction between experimental cycle and burial depth on the germination rate index (GRI) of wild oat (*Avena fatua*), barley and wheat in response to pyroligneous acid dose when applied at 200 L ha^{-1} to the soil surface and grown in a greenhouse in Saskatoon, SK, in 2021.

Cycle	Burial	Emergence rate index					
		Wild oat		Barley		Wheat	
1	0	6.9004	C[2]	19.43	A	18.33	A
1	1	5.099	D	17.60	B	16.46	B
2	0	8.3977	B	11.47	C	12.21	C
2	1	9.7586	A	11.34	C	12.09	C

[1] Pyroligneous acid was applied at 200 L ha-1 to the soil surface. Plants were grown in an incubator with conditions set to 12-h

[2] A different letter within the same column indicates a significant difference (α=0.05) using Tukey's honest significant different test for means comparison.

For oats, there was an impact of cycle ($p<0.01$) and burial ($p=0.01$) but there was no impact of dose ($p=0.27$), a dose by burial interaction ($p=0.98$), a cycle by dose interaction ($p=0.36$), a cycle by burial interaction ($p=0.78$), or a three way interaction between cycle, dose, and burial ($p=0.98$). For the significant impact of burial, oats demonstrated a higher ERI when deposited on the surface (6.4) compared to buried 1 cm in the soil depth (5.3). For the significant effect of experimental cycle, the first cycle demonstrated a higher ERI (6.7) than the second cycle (4.9).

For barley, there was an impact of cycle ($p<0.0001$), burial ($p<0.0001$), and a cycle by burial interaction ($p=0.0005$) but there was no impact of dose ($p=0.8464$), a dose by burial interaction ($p=0.8597$), a cycle by dose interaction ($p=0.8154$), or a three-way interaction between cycle, dose, and burial ($p=0.6441$). The interaction between experimental cycle and burial is characterized by a reduction in ERI for experimental cycle 1 which was not detected in experimental cycle 2 (Table 7).

For wheat, there was an impact of experimental run ($p<0.0001$), burial depth ($p<0.0001$), and an interaction between experimental run and burial depth ($p<0.0001$) but no impact of PA dose (0.1967), a PA dose by burial depth interaction ($p=0.2887$), an experimental run by PA dose interaction ($p=0.5737$), or a three way interaction between experimental run, PA dose, and burial depth ($p=0.5035$). Similar to barley, wheat demonstrated a lower ERI in experimental run two (Table 7), which did not respond to planting depth while planting depth was significant in cycle 1.

Phase 2. Germination Interaction. For wild oat, there was an impact of PA ($p<0.0001$), KNO3 ($p<0.0001$), and interaction between PA and KNO3 on wild oat germination ($p<0.0001$) on the GRI. There was also an impact of cycle ($p<0.0001$) and significant higher order interactions with PA and KNO3 ($p<0.05$). The trend between the to cycles was largely similar though the overall GRI was reduced in the second cycle (Table 8).This interaction was characterized by minimal emergence in PA treatments while the KNO3 induced dormancy in all treatments, as well as the 10% PA treatment.

Table 8: Impacts of pyroligneous acid and potassium nitrate used as wetting solutions in petri dishes on wild oat (*Avena fatua*) and oat germination rate index.

Pyroligneous acid	Potassium nitrate	Germination rate index			
		Wild oat		Oat	
%	Kg N ha^{-1}	First run	Second run	First run	Second run
0	0	4 ab	1 c	7 a	3 bc
0	125	0 d	0 d	0 d	0 d
0.1	0	6 a	2 bc	4 ab	2 bc
0.1	125	0 d	0 d	0 d	0 d
1	0	4 ab	1 cd	4 ab	1 c
1	125	0 d	0 d	0 d	0 d
10	0	0 d	0 d	0 d	0 d
10	125	0 d	0 d	0 d	0 d

*Values are back-transformed least square estimates.

For oats, there was a similar impact of PA ($p<0.0001$), KNO3 ($p<0.0001$), and an interaction between PA and KNO3 ($p<0.0001$) on oat GRI. There was also an impact of experimental run ($P=0.0003$), and higher order interactions with experimental run including a three way interaction with KNO3 and PA ($P=0.0445$). The interaction was characterized similarly with wild oat, where complete dormancy was induced by KNO3 and 10% PA (Table 8).

For barley, assumptions could not be met so cycles were analyzed separately. For the both cycles there was an impact of KNO3 ($P<0.0001$), PA ($P<0.0001$), and an interaction between KNO3 and PA ($P<0.0001$). Similar to oats and wild oat, barley only germinated in the control, 0.1% PA alone, and 1% PA alone but the degree of germination between runs varied (Table 9).

Table 9. Impacts of pyroligneous acid and potassium nitrate used as wetting solutions in petri dishes on barley and wheat germination rate index.

Pyroligneous acid %	Potassium nitrate Kg N ha-1	Germination rate index			
		Barley		Wheat	
		Cycle 1	Cycle 2	Cycle 1	Cycle 2
0	0	25 a	6 a	25 a	6 a
0	125	0 c	0 b	0 c	0 b
0.1	0	25 a	16 a	25 a	16 a
0.1	125	0 c	0 b	0 c	0 b
1	0	14 b	6 a	14 b	6 a
1	125	0 c	0 b	0 c	0 b
10	0	0 c	0 b	0 c	0 b
10	125	0 c	0 b	0 c	0 b

*Values for barley are back-transformed least square estimates while for wheat they are least square estimates. Differences in letter groups within a barley column indicates a significant difference using Tukey's honestly significant different test. Differences between cells within the wheat columns indicates a significant difference ($\alpha=0.05$).

For wheat, there was a significant impact of PA ($p<0.0001$), KNO3 ($p<0.0001$), and an interaction between PA and KNO3 ($p<0.0001$) on wheat GRI. There was also a significant experimental run effect and interaction with both PA and KNO3 factors including a three-way interaction ($p<0.0001$). This interaction was similarly categorized as the other crops, with germination occurring at 0, 0.1, and 1% PA but otherwise, no germination and no treatments indicate reliable stimulation at these doses (Table 9).

These experiments, when taken together with the previous dose response work, show that in petri dish environments, the concentration which induces dormancy is between 1 and 5% PA for all species.

Emergence interaction. For wild oat, there was a significant effect of burial depth ($p<0.0001$) and a significant three way interaction between cycle, fertilizer, and PA ($p=0.0209$) but cycle was not significant ($p=0.8526$), PA was not significant ($p=0.1953$), KNO3 was not significant ($p=0.0629$), nor any of the other interactions ($p>0.05$). While a higher order interaction was significant in the ANOVA, Tukey's means comparison did not show any differences between means. Considering both cycles, wild oat ERI for surface deposited seed was 4.7 and increased to 5.9 when buried.

For oat, there was an impact of cycle ($p<0.0001$), depth ($p=0.0227$), PA ($p=0.0193$), but not KNO3 ($p=0.6988$). There was a significant cycle by depth interaction ($p<0.0001$) but no other interactions were significant ($p>0.05$). For the significant effect of PA on oat ERI, there was a reduction by 1 and 10% spray solutions compared to the nontreated control, so no indication of stimulation at these levels for oat (Table 9). For the significant interaction

between burial depth and cycle, burial at 1 cm depth in field soil resulted in increase ERI for the second cycle but not the first, and the second cycle had a higher ERI compared to the first for the 1 cm burial depth (Table 10).

Table 10. The impact of applying pyroligneous acid at varying solutions at 200 L ha^{-1} in a spray chamber on wild oat emergence in pots in an incubator in Saskatoon, SK, in 2021.

Pyroligneous acid	Emergence rate index	
	Oat	Barley
%		
0	6 a	9 b
0.1	6 ab	10 ab
1	5 b	10 a
10	5 b	9 ab

*Values are least square estimates.

Table 11. The influence of burial depth and experimental run on oat emergence rate index in an incubator in Saskatoon, SK in 2021.

Experimental run	Depth	Emergence rate index		
		Oat	Barley	Wheat
1	0	5 b	7 b	7 d
1	1	4 c	11 a	9 c
2	0	5 b	10 a	11 a
2	1	7 a	11 a	10 b

*Values are least square estimates.

For barley, there was a significant effect of experimental run ($p<0.0001$), burial depth ($p<0.0001$), PA ($p=0.0342$), an experimental run by depth interaction ($p<0.0001$), and an experimental run by KNO3 interaction ($p=0.0424$). There was no impact KNO3 ($p=0.2020$) nor any other interactions ($p>0.05$). A low dose of 1% PA did increase barley ERI compared to the control (Table 10). A similar trend was observed for the impact of burial depth across both barley runs except the first cycle's unburied treatment had a lower ERI compared to all other treatments (Table 11).

For wheat, there was a significant effect of experimental run ($p<0.0001$), KNO3 ($p<0.0001$), and a experimental run by burial depth interaction ($p<0.0001$), but no impact of depth ($p=0.0717$), PA ($p=0.6610$), nor any higher order interactions ($p>0.05$). The KNO3 effect indicated that there was a significant reduction in ERI for wheat treated with 125 kg N ha^{-1} (9 ERI) compared to the non-treated control (10 ERI). The cycle by burial depth interaction was characterized by differing ERI between burial depths and between runs (Table 11).

Discussion. The wild oat biotype used in this study (HR13-153) demonstrated a higher base GRI (6.6 to 7.2) (Table 4) (5.1 to 9.7) (Table 9) than previously reported for the Alberta population (GRI = 3.7) (Saini et al., 1986). There, the authors stored the seed at -24 C and experiments were conducted over a 2 year period. Notably, the authors report consistent levels of dormancy with storage at this temperature over 9 months of storage. The subjection of the fresh seed to -25 C may have exerted an external stimuli on the seed to promote endodormancy, which complicates studying cold-mediated endodormancy with what is generally considered after-ripening, which is considered an internal force. White light is dormancy-releasing for partially-dormant seeds following seed

production, which was found across many populations from the United Kingdom (Hilton and Bitterli, 1983). Therefore, the increased GRI of the current study may be due to the inclusion of light in the growth chamber, which was included to emulate the post-harvest environment and no-till production with minimal burial of seed. Further studies should examine the interaction of light with other external stimuli for dormancy-release of wild oat.

Wild oat nitrogen insensitivity for germination stimulation in petri dishes was not expected. An increase in germination percentage was observed between 0 and 100 mM previously for a wild oat population from northern Alberta (Saini et al., 1986). The authors also do not report any dormancy-inducing effects of the 100 mM treatment. Alternatively, use of 100 mM KNO3 did reduce the GRI from 3.7 to 3.3 (Sharma et al., 1976), which is a similar trend to the current results. The authors also report a germination increase of over 20% with 10 mM.

Wild oat germination has previously been shown to be response to smoke solutions, where a 1:10000 solution increased the germination rate during the first three days of incubation (Kępczyński et al., 2006). The authors also found that there was interaction and increased germination when GA_3 (10^{-5} to 10^{-4} M) was included with smoke solutions. Results differ from another experiment incubating wild oat in smoke-water solutions, where increased germination was observed when incubating with 5, 10, 20, and 50% solutions while only the 100% solution inhibited germination of freshly produced wild oat seed (Adkins and Peters, 2001). This may be due to the concentration of smoke signal gathered or the source vegetation used during the combustion process (Grewal et al., 2018). The authors also found that when after-ripening was permitted to proceed for 8 to 12 weeks at room temperature (20 to 25 C), indicating an increased efficacy of the smoke water signals to the plant when over-ripening is overcome. This is promising for potential spring applications since some degree of after-ripening has occurred from harvest to pre-planting.

e) **Conclusions and Recommendations** – *Highlight significant conclusions based on the discussion and analysis provided in the previous section with emphasis on the project objectives specified above; also provide recommendations for the application and adoption of the project results and identify any further research, development and communication needs, if applicable*.

This research demonstrates a novel spray use pattern, applying pyroligneous acid at 50 to 100% solutions at 200 L ha^{-1} on freshly-matured wild oat to increase the emergence velocity through the after-ripening portion of endodormancy, as measured by the emergence rate index (Figure 2). Barley may be sensitive to pyroligneous acid at 1% solution applied at 200 L ha^{-1}, with an increase from 9 to 10 ERI (Table 9). These use-patterns should provide a baseline for experimental treatments for field-experimentation to optimize PA applications on established wild oat seedbank. Additional application volumes should be tested in the field as well as their impacts on additional crops, weeds, the microbiome, pathogens, and insects. The wild oat biotype used in this research was insensitive to nitrogen across a wide range, indicating that using nitrogen to stimulate emergence of the wild oat seedbank may have variable results depending on how widespread nitrogen insensitivity is in this species. Applying ≥50% solutions at 200 L ha^{-1} may have herbicidal activity on emerged vegetation, which requires additional research.

f) A comprehensive Final Financial Statement that summarizes the total income and expenditures attributable to the funders' Funding. (Please see corresponding email for a separate file).

AAFC Project # A10500 AGR 17897

STIMULATING GERMINATION OF WILD OAT AND VOLUNTEER CEREALS FROM THE SOIL SEED BANK

Financial Statement as at January 27, 2022

Dr Shaun Sharpe

Approved Budget	**$**	**57,750**
Funds Received	**$**	**43,313**

	Budget	Funds Received	Expended	Committed	Balance
Non-Pay Operating	52,500.00	39,375.45	39,393.88	13,106.12	-13,124.55
SSC - A07916	5,250.00	3,937.55	5,250.00	0.00	-1,312.45
Total	**57,750.00**	**43,313.00**	**44,643.88**	**13,106.12**	**-14,437.00**

G:\Finance\External Funding & MII\Collaborator Reports\A10500 Sharpe Jan 2022.xls

Report Prepared by: Marla Pederson
Phone: (306) 752-6406
1/27/2022

g) **Acknowledgements** – *Include actions taken to acknowledge support by the Funders.*

This research was funded by the Manitoba Crop Alliance, the Saskatchewan Oat Development Commission, and the Saskatchewan Wheat Development Commission. The authors gratefully thank Taylor Kaye, Andrew Batycki, Jillian Watson, and Sylvia Li for their technical assistance. The authors also gratefully thank the greenhouse staff of the Saskatoon Research and Development Center for their preparation of the potting soil, assistance in watering, and pest prevention activities. The authors also gratefully acknowledge Plant Genome Resource Canada for supplying the seed used in the dose response experiments. This research will be presented at the Weed Science Society of America and the Canadian Weed Science Society joint annual meeting as well as the Crops and Soils workshop in Saskatchewan. At both meetings, the funders support was acknowledged for the presentation and poster. Please see poster below.

h) **Literature Cited**

Adkins SW, Peters NCB (2001) Smoke Derived from Burnt Vegetation Stimulates Germination of Arable Weeds. Seed Science Research 11:213-222

Agenbag GA, de Villiers OT (1989) The Effect of Nitrogen Fertilizers on the Germination and Seedling Emergence of Wild Aat (*A. fatua* L.) Seed in Different Soil Types. Weed Res. 29:239-245

Awada L, Gray RS, Nagy C (2016) The Benefits and Costs of Zero Tillage RD&E on the Canadian Prairies. Can. J. Agric. Econ. 64:417-438

Beckie HJ, Flower KC, Ashworth MB (2020) Farming without Glyphosate? Plants 9:96

Beckie HJ, Leeson JY, Thomas AG, Brenzil CA, Hall LM, Holzgang G, Lozinski C, Shirriff S (2008) Weed Resistance Monitoring in the Canadian Prairies. Weed Technol. 22:530-543

Beckie HJ, Shirriff SW, Leeson JY (2017) Saskatchewan Weed Survey of Herbicide-Resistant Weeds in 2014-2015: Agriculture and Agri-Food Canada, Saskatoon Research & Development Centre. 37 p

Beckie HJ, Shirriff SW, Leeson JY (2018) Manitoba Weed Survey fo Herbicide-Resistant Weeds in 2016: Agriculture and Agri-Food Canada, Saskatoon Research & Development Centre. 49 p

Beckie HJ, Shirriff SW, Leeson JY, Hall LM, Harker KN (2019) Alberta Weed Survey of Herbicide-Resistant Weeds in 2017: Agriculture and Agri-Food Canada, Saskatoon Research & Development Centre. 39 p

Beckie HJ, Thomas AG, Légère A, Kelner DJ, Van Acker RC, Meers S (1999) Nature, Occurrence, and Cost of Herbicide-Resistant Wild Oat (*Avena fatua*) in Small-Grain Production Areas. Weed Technol. 13:612-625

Bell AR, Nalewaja JD (1968) Competition of Wild Oat in Wheat and Barley. Weed Sci. 16:505-508

Grewal A, Abbey L, Gunupuru LR (2018) Production, Prospects and Potential Application of Pyroligneous Acid in Agriculture. J. Analyt. Appl. Pyrolysis 135:152-159

Heap IM, Murray BG, Loeppky HA, Morrison IN (1993) Resistance to Aryloxyphenoxypropionate and Cyclohexanedione Herbicides in Wild Oat (*Avena fatua*). Weed Sci. 41:232-238

Hilton JR, Bitterli CJ (1983) The Influence of Light on the Germination of *Avena fatua* L. (Wild Oat) Seed and Its Ecological Significance. New Phytol. 95:325-333

Hobson KA, Bayne EM, Van Wilgenburg SL (2002) Large-Scale Conversion of Forest to Agriculture in the Boreal Plains of Saskatchewan. Conserv. Biol. 16:1530-1541

Jana S, Achar SN, Naylor JM (1979) Dormancy Studies in Seed of *Avena fatua*. 10. On the Inheritance of Germination Behaviour. Can. J. Bot. 57:1663-1667

Kępczyński J, Białecka B, Light ME, van Staden J (2006) Regulation of *Avena fatua* Seed Germination by Smoke Solutions, Gibberellin A3 and Ethylene. Plant Growth Regulation 49:9-16

Lang G, Early J, Martin G, Darnell R (1987) Endo-, para-, and ecodormancy: physiological terminology and classification for dormancy research. HortScience 22:371-377

Leeson JY (2016) Saskatchewan Weed Survey of Cereal, Oilseed and Pulse Crops in 2014 and 2015: Agriculture and Agri-Food Canada, Saskatoon Research Centre. 356 p

Leeson JY, Gaultier J, Grenkow L (2017) Manitoba Weed Survey of Annual Crops in 2016: Agriculture and Agri-Food Canada, Saskatoon Research Centre. 203 p

Leeson JY, Hall LM, Neeser C, Tidemann BD, Harker KN (2019) Alberta Weed Survey of Annual Crops in 2017: Agriculture and Agri-Food Canada, Saskatoon Research Centre. 275 p

Mangin AR, Hall LM, Beckie HJ (2016) Triallate-resistant Wild Oat (*Avena fatua* L.): Unexpected Resistance to Pyroxasulfone and Sulfentrazone. Can. J. Plant Sci. 97:20-25

Martinson K, Durgan B, Forcella F, Wiersma J, Spokas K, Archer D (2007) An Emergence Model for Wild Oat (*Avena fatua*). Weed Sci. 55:584-591

Naylor JM, Jana S (1976) Genetic Adaptation for Seed Dormancy in *Avena fatua*. Can. J. Bot. 54:306-312

Norsworthy JK, Ward SM, Shaw DR, Llewellyn RS, Nichols RL, Webster TM, Bradley KW, Frisvold G, Powles SB, Burgos NR, Witt WW, Barrett M (2012) Reducing the Risks of Herbicide Resistance: Best Management Practices and Recommendations. Weed Sci. 60:31-62

O'Donovan JT, de St. Remy EA, O'Sullivan PA, Dew DA, Sharma AK (1985) Influence of the Relative Time of Emergence of Wild Oat (*Avena fatua*) on Yield Loss of (*Hordeum vulgare*) and Wheat (*Triticum aeiticum*). Weed Sci. 33:498-503

Saini HS, Bassi PK, Spencer MS (1986) Interactions among Ethephon, Nitrate, and After-Ripening in the Release of Dormancy of Wild Oat (*Avena fatua*) Seed. Weed Sci. 34:43-47

Sawhney R, Naylor JM (1982) Dormancy Studies in Seed of *Avena fatua*. 13. Influence of Drought Stress During Seed Development on Duration of Seed Dormancy. Can. J. Bot. 60:1016-1020
Sharma MP, Born WHV, McBeath DK (1976) Studies on the Biology of Wild Oats. I. Dormancy, Germination and Emergence. Can. J. Plant Sci. 56:611-618
Shirtliffe SJ, Entz MH, Van Acker RC (2000) *Avena fatua* development and seed shatter as related to thermal time. Weed Sci. 48:555-560
Thomas AG (1976) 1976 Weed Survey of Cultivated Land in Saskatchewan: Agriculture Canada, Regina Research Station. 93 p
Thomas AG, Wise RF (1983) Weed Surveys of Saskatchewan: Cereal and oilseed Crops from 1976 to 1979: Agriculture Canada, Regina Research Station. 260 p
Tidemann BD, Hall LM, Harker KN, Alexander BCS (2016) Identifying Critical Control Points in the Wild Oat (*Avena fatua*) Life Cycle and the Potential Effects of Harvest Weed-Seed Control. Weed Sci. 64:463-473
Tidemann BD, Hall LM, Harker KN, Beckie HJ (2017a) Factors Affecting Weed Seed Devitalization with the Harrington Seed Destructor. Weed Sci. 65:650-658
Tidemann BD, Hall LM, Harker KN, Beckie HJ (2017b) Potential Benefit and Risk of Fluridone as a Fall Germination Stimulant in Western Canada. Weed Technol. 31:773-780
Weir J, Johnson EA (1998) Effects of escaped settlement fires and logging on forest composition in the mixedwood boreal forest. Can. J. For. Res. 28:459-467

i) **Appendices** - *If necessary, include any materials supporting the previous sections, e.g. detailed data tables, maps, graphs, specifications.*

j) **Other** – (*e.g., extension meetings; papers produced; conference presentations made; personnel involved; equipment bought; photos; project materials developed).*

A manuscript for peer-reviewed publication is being developed. It will be submitted to a journal such as Agronomy or the Canadian Journal of Plant Science.

Research personnel involved in this project include Taylor Kaye, a research technician working with Dr. Sharpe at the Saskatoon Research and Development Centre and three students through the Federal Student Workplace Exchange Program ,Sylvia Li, Jillian Watson, and Andrew Batycki.

Conference Presentations.

Stimulating Germination and Emergence of Wild Oat (*Avena fatua*) and Volunteer Cereals. Shaun Sharpe, Taylor Kaye, and Breanne D. Tidemann. Poster Presentation for the joint annual meeting of the Canadian Weed Science Society and the Weed Science Society of America. Upcoming virtual conference.

Wild oat is a widespread threat to spring annual crop production on the Canadian Prairies. Multiple herbicide-resistant wild oat biotypes have been identified with resistance towards Groups 1, 2, and 15 herbicides. Infesting populations are difficult to manage due to complex dormancy, a long emergence window, a long-persisting seedbank, and seed shatter corresponding to typical crop harvest timings. Management strategies for targeting the seedbank are limited. Wild oat has previously demonstrated a positive germination response to exogenously applied products such as potassium nitrate and gibberellins. Understanding the responsiveness of exogenously applied stimulants to wild oat and volunteer cereals may promote emergence at more desirable times such as pre-seeding to utilize broad-spectrum herbicides or post-harvest to utilize a killing frost. The study objective was to evaluate the suitability of applying exogenous potassium nitrate and pyroligneous acid for promoting germination and emergence of wild oat and volunteer wheat, barley, and oats. Dose response experiments were conducted in control environments in both petri dishes and pots. The wild oat biotype used was insensitive to varying concentrations of potassium nitrate. In petri dishes, concentrations of 5% or greater pyroligneous acid induced dormancy for wild oat, oat, barley, and wheat. Pyroligneous acid did enhance the emergence rate index for wild oat when applied to pots either with or without field soil. There was no impact of pyroligneous acid dose on wheat, barley, or oat emergence rate index. Results demonstrate a suitable use-pattern for stimulating emergence of wild oat from freshly mature seed with pyroligneous acid using conventional spray equipment. Additional experiments are required to determine the efficacy of this product in the field and impact of additional stimulants on its efficacy.

Stimulating Germination and Emergence of Wild Oat (*Avena fatua*) and Volunteer Cereals

Shaun M. Sharpe[1], Taylor Kaye[1], and Breanne D. Tidemann[2]
[1]Saskatoon RDC, Agriculture and Agri-Food Canada, [2]Lacombe RDC, Agriculture and Agri-Food Canada

Introduction

- Wild oat is a major weed to Prairie annual cropping systems.
- The seedbank has been identified as the critical part of its lifecycle to target for management (Tidemann et al. 2016).
- Compounds to manage wild oat dormancy have been studied but a use-patterns for field applications are not well understood.
- Stimulating the seedbank post-harvest or pre-seed may provide additional control options and reduce infestations.

Methodology

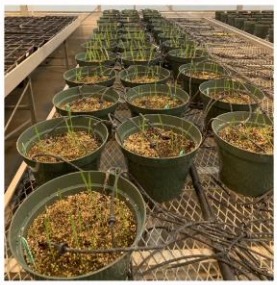

Figure 1. Examples of wild oat and cereal propagation to acquire freshly harvested seed for experimentation.

- Fresh seed was produced for all experiments in the greenhouse (Figure 1) to ensure endodormancy of wild oat.
- Dose response experiments for wild oat, oat, barley, and wheat. Separate experiments for pyroligneous acid and potassium nitrate.
- Germination - Petri dish experiments (25 seeds, 2 pieces of filter paper, sealed with parafilm).
- Emergence - seeds were buried in 1 cm of field soil or deposited on the surface for pots.

Methodology

- Pyroligneous acid doses: 0, 5, 10, 20, 50, and 100% solutions. Potassium nitrate doses: 0, 0.1, 1, 10, and 100 mM.
- Each solution was used as the wetting solution in petri dishes. Solution was sprayed at 200 L ha^{-1} for potted experiments.
- Germination or emergence rate index used to measure the speed of germination in response to stimulants (Sharma et al. 1976).
- ANOVA was conducted in SAS and if a dose response effect was significant, regression was conducted using SigmaPlot.

Figure 2. Example of experimental setup after treatment application, with pots and petri dishes within the same incubator.

Results

- Among the four test species, wild oat and oat demonstrated endodormancy of fresh seed while wheat and barley emerged very rapidly (Figure 3).
- Wild oat germination and emergence was not stimulated by potassium nitrate.
- Pyroligneous acid did promote complete dormancy in all tested species when used as the wetting solution in petri dishes.

Results

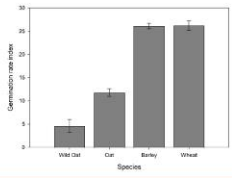

Figure 3. Mean germination rate index (n=8) of freshly produced seed of wild oat, oat, barley, and wheat in the non-treated control petri dishes in an incubator for the pyroligneous acid dose response experiments conducted in Saskatoon, SK.

- Wild oat emergence was impacted by pyroligneous dose (p=0.05) and a burial by cycle interaction (p<0.01) but there was no interaction of burial and dose (p=0.58).
- Spraying pyroligneous at 200 L ha^{-1} did increase the emergence rate index and was not impacted by burial depth for wild oat (Figure 4).

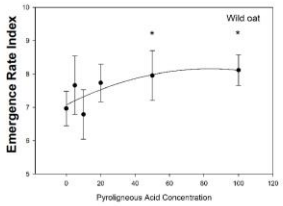

Figure 4. Wild oat emergence rate index response to increasing concentrations of pyroligneous acid applied at 200 L ha-1. Values are an average of both the 0 and 1 cm seeding depth. An asterisk confirms a significant difference between the nontreated control and that treatment using a t-test (α=0.05) for confirmation purposes.

Results

Table 1. Interaction between experimental cycle and burial depth on the emergence rate index of wild oat, barley and wheat in response to pyroligneous acid dose when applied at 200 L ha-1 to the soil surface and grown in a greenhouse in Saskatoon, SK, in 2021.

Cycle	Burial	Emergence rate index		
	(cm)	Wild oat	Barley	Wheat
1	0	6.9 C	19.4 A	18.3 A
1	1	5.1 D	17.6 B	16.5 B
2	0	8.4 B	11.5 C	12.2 C
2	1	9.8 A	11.3 C	12.1 C

Conclusion

- Wheat, barley, oat, and wild oat seed dormancy was induced with pyroligneous acid of at least 5% when used as a wetting solution.
- A novel spray pattern for pyroligneous acid was identified for reducing the after-ripening period for freshly matured wild oat. Other species were not impacted.
- Impacts of pyroligneous acid on field emergence of wild oat requires additional study
- The impacts on additional weed species, crop, and non-target organisms (insects, microbiome) require additional study.

References

- Tidemann BD, Hall LM, Harker KN, Alexander BCS (2016) Identifying Critical Control Points in the Wild Oat (*Avena fatua*) Life Cycle and the Potential Effects of Harvest Weed-Seed Control. Weed Sci. 64:463-473
- Sharma MP, Vander Born WH, McBeath DK (1976) Studies on the Biology of Wild Oat 1. Dormancy, Germination and Emergence. Canadian Journal of Plant Science 56:611-618

Acknowledgements

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- The authors are grateful for the technical assistance of Sylvia Li, Jillian Watson, and Andrew Batycki.
- The authors are grateful for Plant Genome Resource Canada for providing cereal seed.

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Evaluation of potassium nitrate and pyroligneous acid as seedbank stimulants for wild oat and volunteer cereals. Shaun M. Sharpe, Taylor Kaye, and Breanne D. Tidemann. Oral presentation for the upcoming Soils and Crops Workshop in Saskatoon, SK for the 2022 virtual meeting.

Wild oat is a widespread threat to annual crop production on the Canadian Prairies. Wild oat infestations are challenging to manage due to complex seed dormancy, a persistent seedbank, a long emergence window, later flushes after in-crop herbicides are applied, and seed shatter corresponding to typical crop harvesting operations. Herbicide resistance to in-crop Group 1 and 2 herbicides has made managing wild oat infestations difficult and requires additional herbicide inputs to achieve control. Production inputs which target wild oat seed within the soil seedbank may benefit producers by promoting wild oat emergence either at beneficial times, such as post-harvest, or shortening the emergence window for a more consistent flush. Dose response experiments were conducted in controlled environments to determine the efficacy of pyroligneous acid and potassium nitrate in promoting seed germination and emergence of wild oat and volunteer oat, barley, and wheat. Germination experiments were conducted in petri dishes and emergence experiments were conducted in pots. The wild oat biotype did not demonstrate a response to an increasing potassium nitrate dose in petri dishes or pots, indicating insensitivity. There was also no impact of potassium nitrate dose on emergence of volunteer oat, barley, and wheat. Dormancy was induced in all four species when exposed to at least 5% solution of pyroligneous acid in petri dishes. Pyroligneous acid increased the emergence rate index for wild oat when at least 20% solutions were applied at 200 L ha-1. Results indicate that pyroligneous acid can be used as an emergence stimulant when applied through a conventional spray system in controlled environments. Additional research is required for field validation and efficacy in post-harvest and pre-seed scenarios.

k) An invoice for each Funding Agency

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