Impact of allelopathic cover crops and its termination method in cash crops grown subsequent season

More than 60% of weed management is through recurring herbicide applications, leading increased instances of weed resistance. Allelopathy is the influence, usually detrimental, of one plant on another, where toxic substances are released when a plant dies, or produced through decaying tissue(Zimdahl R.L., 2018). These secondary metabolites may establish direct or indirect harmful or beneficial effects (Reigosa et al., 2006). Allelopathy can affect the growth and yield of another crop (Batish et al., 2001), b) develop autotoxicity, meaning chemicals expelled from plant residues of a species can hinder the growth of seedlings of the same species (Yu and Matsui, 1997). Thus, if managed properly, allelopathy can be a great alternative in weed management.

Table 1. Experimental treatments outlining cover crop species, seeding rates, and termination methods.

Cover crop	Seeding rate Pounds acre^{-1}	Cover crop	Seeding rate Pounds acre^{-1}	Termination
None	0	None	0	Incorporated
Rye	180			
Annual ryegrass	44			
Hairy vetch	40			
Sunflower	12			
Rye	90	Annual ryegrass	22	
		Hairy vetch	20	
		Sunflower	12	
Annual ryegrass	22	Hairy vetch	20	
Hairy vetch	20	Sunflower	12	
None	0	None	0	Roller crimped
Rye	180			
Annual ryegrass	44			
Hairy vetch	40			
Sunflower	12			
Rye	90	Annual ryegrass	22	
		Hairy vetch	20	
		Sunflower	12	
Annual ryegrass	22	Hairy vetch	20	
Hairy vetch	20	Sunflower	12	

The experiment was located at two sites at Lakeland Agricultural Research Association. These sites are St Paul (54°5’N, 110°15’W), and Fort Kent (54°18’N, 110°37’W). Aside from the herbicide burndown treatments there were no further applications of herbicide for the rest of the growing season. Rye (Secale cereal L), annual ryegrass (Lolium multiflorum L.), hairy vetch (Vicia villosa L.), sunflower (Helianthus annus L.) were sown at 4.9, 4.5, 20.2 and 1.3 g m2 and mixtures of these crops (rye + ryegrass, rye + hairy vetch, rye + sunflower) were also sown. Except for sunflower, seeding rate of all other cover crop species was doubled. The experiment was set up as a four replicate, complete random design. Hand weeding, either by stirrup hoe and/or a wheel stirrup hoe between seed rows around the first week of June. The split plot factor is the cover crop termination style: roller crimped or incorporated. An untreated control, where no cash crop is seeded will also be included.

In the following growing season, cash crops such as canola, wheat or peas are planned to be seeded as monocrop at each site respectively. Much like the first study year, soil samples will be collected for chemical analysis, a burndown herbicide application will be broadcasted before seeding and fertilization will be adjusted to target yields such as 40, and 50, for canola and wheat respectively (Government of Alberta 2024), as peas will not be fertilized. Harvest per plot will be weighed and recorded.

For both study years, a quadrat of 25X25 cm will be situated randomly across the plot. In June, July, and August, weed species and number of weeds per species were counted in one of these quadrats (species richness). Quadrat selection was random. Afterwards, biomass was taken out of this one quadrat and separated as weeds and cover crop species. For the second study year, biomass will be taken before the cash crop harvest and separated as weeds, cash crop and if present, cover crop harvest.

Crop and weed biomass, land equivalent ratio and actual yield loss

Crop and weed biomass, land equivalent ratio (LER) and actual yield loss (AYL) were different among treatments ($P<0.0001$). Cover crop biomass was expected to be greater in cover crops such as sunflower in contrast to annual ryegrass. As such, plots with sunflower + hairy vetch had more biomass compared to plots where annual ryegrass was seeded as a sole crop. Weed biomass on the other hand was greater in plots where sunflower was sown with annual ryegrass and less biomass was found in plots where annual ryegrass was interseeded with rye. This is important to notice because annual ryegrass+ rye, which is one of the lightest cover crop treatments, was able to suppress more weeds than treatments where sunflower was sown (Table 1).

Table 4. Cover crop and weed biomass values, biomass land equivalent ratio (LER) and actual yield loss (AYL) in control (no cover crop seeded) and cover crop seeded plots with either annual ryegrass, rye, hairy vetch and sunflower in monocrop and intercrop systems in Fort Kent and in St. Paul Alberta on the growing season of 2024

		$g\ m^{-2}$							
		Cover crop		Weed		LER		AYL	
Control				2156.00	A	0.00			
Annual ryegrass		1518	E	251.00	CD	1.00	B	1.00	A
	Hairy vetch	1576.9	DE	280.00	CD	1.26	B	0.27	B
	Rye	1866	DE	44.60	G	1.23	B	0.02	B
	Sunflower	3037	BC	160.00	DE	1.48	AB	0.20	B
Hairy vetch		1807	DE	321.00	BC	1.00	B	1.00	A
	Rye	1918	DE	207.70	EF	1.25	B	-0.36	C
	Sunflower	3013	A	488.00	B	1.99	A	0.08	B
Rye		1960	CDE	58.80	FG	1.00	B	1.00	A
	Sunflower	2168	CD	93.70	FG	1.19	B	-0.02	BC
Sunflower		4564	AB	768.00	B	1.00	B	1.00	A
	Error	420.72		131.4		0.2		0.3	

*Difference letters indicate significance between values ($P<0.05$, N=80)

Values observed in LER demonstrate there is no cover crop intercrop treatment that yields less than their respective monocrops. Also, that there is an increase of 99% and 48% in plots where sunflower was intersown with hairy vetch and annual ryegrass respectively in comparison to the other intercrop treatments. Yield loss (AYL) shows that the rye + hairy vetch system is disadvantageous compared to any cover crop mix with annual ryegrass, as well as the sunflower+ hairy vetch system. Indeed, rye was observed to grow more aggressively than sunflower. Highest LER was found in where sunflower+ hairy vetch was sown but AYL shows that both species will not thrive in synergy because there will be far more hairy vetch individuals than those of sunflower. Furthermore, LER and AYL values in annual ryegrass + sunflower mixtures show this system as a great option for forage value and ground coverage. Hairy vetch + sunflower can also be an option but hairy vetch, like rye tends to grow more aggressively than sunflower, thus reducing the AYL coefficient. Further outcomes will help to strengthen these results or provide us with even more startling differences.

Differences in weed biomass, number of weed individuals, and number of weed species across treatments

Cover crop biomass as well as weed biomass, number of individuals and species differences among treatments were calculated as follows: Cover crop biomass from annual ryegrass, hairy vetch, rye and sunflower as sole crop was subtracted to (a) allotted cover crop biomass value from all intercrop mixes that had either of the aforementioned cover crops and (b) cover crop biomass found at each intercrop system that contained either of the aforementioned cover crops. Weed biomass, number of individuals, number of species values and found in plots where no cover crop was seeded were subtracted to (a) values found in all monocrops cover crop species treatments (b) values found in all inter crop cover crop species treatments. Likewise, Weed biomass, number of individuals, and number of species values and found in plots where monocrops of annual ryegrass, hairy vetch, rye and sunflower were sown were subtracted to (c) same values found in all cover crop intercrop mixes that had either of the aforementioned cover crops and (d) same values found at each intercrop system that had the either of the cover crops before mentioned in a monocrop system (Table 2). Table 2 classifies the subtraction as effect minus comparison effect.

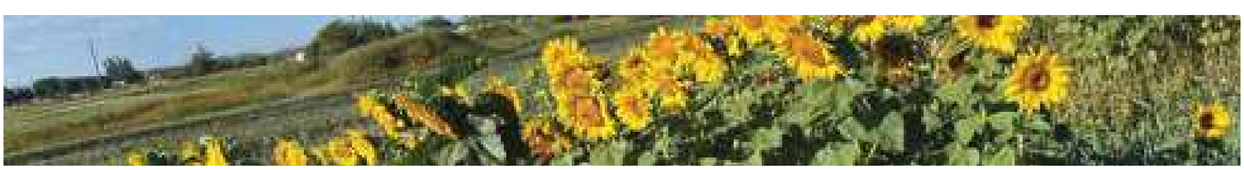
Table 2. Differences* between number of weed individuals in control (no cover crop seeded) and species number versus cover crop monocrops annual ryegrass, hairy vetch, rye and sunflower as well as mixes of these cover crops and differences between annual ryegrass in Fort Kent and in St. Paul Alberta on the growing season of 2024

Effect	Comparison effect	Weed biomass			Weed individuals			Weed species		
		$g\ m^{-2}$			individuals m^{-2}			Weed species		
control	monocrop cover crops	290.82	89.6	*	26.08	11.6	*	0.48	0.2	*
	cover crop mixes	583.48	86.7	*	36.94	11.2	*	0.56	0.2	*
annual ryegrass	annual ryegrass mixes	47.88	92.7	*	6.11	12.0		-0.04	0.2	
rye	rye mixes	336.53	92.7	*	10.78	12.0		0.30	0.2	
sunflower	sunflower mixes	-58.47	92.7		-13.44	12.0		-0.08	0.2	
hairy vetch	hairy vetch mixes	884.77	92.7	*	40.00	12.0	*	0.13	0.2	
annual ryegrass	annual ryegrass mixed with hairy vetch	-74.00	113.6		11.00	14.7		-0.15	0.3	
	annual ryegrass mixed with rye	166.40	113.6	*	20.67	14.7		0.28	0.3	
	annual ryegrass mixed with sunflower	51.00	113.6		-13.33	14.7		-0.27	0.3	
hairy vetch	hairy vetch mixed with annual ryegrass	871.00	113.6	*	50.00	14.7	*	0.08	0.3	
	hairy vetch mixed with rye	835.98	113.6	*	32.33	14.7	*	0.28	0.3	
	hairy vetch mixed with sunflower	946.30	113.6	*	37.67	14.7	*	0.02	0.3	
rye	rye mixed with annual ryegrass	443.40	113.6	*	18.67	14.7		0.44	0.3	
	rye mixed with hairy vetch	167.00	113.6		-7.67	14.7		0.21	0.3	
	rye mixed with sunflower	399.20	113.6	*	20.33	14.7		0.28	0.3	*
sunflower	sunflower mixed with annual ryegrass	-66.30	113.6	*	-28.00	14.7	*	-0.23	0.3	*
	sunflower mixed with rye	-114.00	113.6		-17.00	14.7		-0.17	0.3	
	sunflower mixed with hairy vetch	4.90	113.6		5.67	14.7		0.15	0.3	

*Estimate differences were calculated as values from the mean values from the effect column minus the comparison effect column.

Error values are represented in italics.

*Value significant at P<0.05, N=88

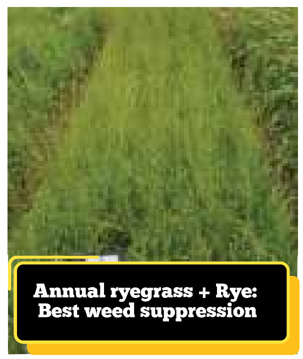


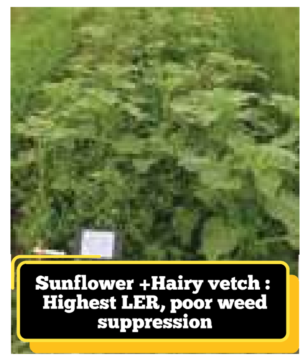
Weed biomass was expected to be greater in control plots. Therefore, the greater the value thus, the greater the impact of the comparison effect (Table 2). Thus, weed biomass collected was heavier in plots where a sole cover crop was sown than when a cover crop was interseeded with another. Total mean number of weed individuals was 151±13 per squared metre. This means that 81% and 74% of weed individuals per metre squared are suppressed in cover crop monocrops and intercrop mixes respectively (Table 2). Similarly, weed species mean value in control plots were 3.5±0.2. Table 2 shows number of weed species in monocrop and intercrop cover crop plots lowered by 84 and 81% respectively. This shows that overall, cover crops suppress more weed biomass but not more weed individuals or weed species when sown in mixture in contrast to cover crops being sown in a monocrop. Possibly, in some plots, such as hairy vetch or rye mixtures, the cover crop biomass was so luscious that it hindered weed seedlings growing underneath. In this way, weed seeds were unable to capture light due to weed smothering and hence there were more weeds seedlings that developed. This in turn produced a decrease in weed biomass but not in weed individuals and weed species in cover crop mixtures.

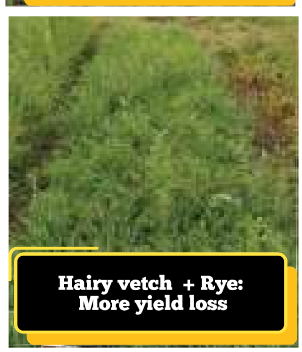
Differences in weed biomass, number of weed individuals, and number of weed species across treatments

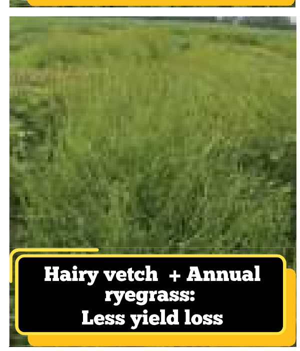
On that note, mixtures of annual ryegrass, rye and hairy vetch have more weed biomass suppression compared to their monocrops of the same species. Difference in number of weed individuals, however, were only significant in hairy vetch. As such weed number was 64% less compared to those found in hairy vetch monocrop plots, given that 112±10 per metre squared individuals were found in them. It is possible that the compound allelopathic effect of both species in an intercrop mixture were more pronounced in mixtures of hairy vetch rather than other mixtures and thus more weed individuals were suppressed.

Weed biomass differences between plots of annual ryegrass as a sole crop and with annual ryegrass+rye showed that annual ryegrass+rye reduces weed biomass by 79% (Table 1 and 2). This however had no effect in number of weed individuals or weed species.









As for hairy vetch, weed biomass in hairy vetch when mixed with either annual ryegrass, rye and sunflower decreased by 56, 55 and 49% respectively (Table 1 and 2) compared from weed biomass taken from hairy vetch monocrop plots. It is likely that hairy vetch +sunflower have a synergistic effect and thus aid to reduce weed biomass better than counter intercrop systems where hairy vetch was sown. Furthermore, given that the number of weed individuals per squared metre was 112±10, weed individuals decreased by 55, 71 and 66% in hairy vetch intersown with either annual ryegrass, rye or sunflower respectively compared to weed individuals found in hairy vetch monocrops (Table 2). This further explains the synergistic effect of hairy vetch with sunflower. Not the same can be said about the hairy vetch+ rye mixtures because it was found that rye inhibited some of hairy vetch propagation and growth. It is possible that interspecific competition between hairy vetch and rye may have aid to reduce number of weed individuals but not weed biomass, as hairy vetch was unable to smother weeds as extensively as it could have done when mixed with sunflower.

Weed biomass in plots where rye was mixed with either annual ryegrass or sunflower reduced weed biomass by 77% and 80% more compared to that found in plots sown to rye alone (Table 1 and 2). It is important to note that in rye+ sunflower mixture, few sunflower individuals were observed which means that rye not only demonstrated to be highly allelopathic but also propagated aggressively. Thus, it is not recommended to seed rye and sunflower in mixture at the seeding rates proposed as it may hinder sunflower growth.

Sunflower mixtures with annual ryegrass had a 1, 20 and 6% increase in weed biomass, weed individuals and weed species respectively compared to sunflower monocrops. Mean values for weed individuals were 146±13. This means one or both of the following (a) annual ryegrass and sunflower allelopathy is antagonistic, and it is hindering growth of either cover crop rather than reducing weed growth or (b) annual ryegrass is likely affected by sunflower growth and as such it is impeding for annual ryegrass to propagate and reduce growth of surrounding weeds.

Relative neighbour effect (RNE) was the same across treatments (P=0.9823), we hypothesize that as the project continues this will change. It is expected that the cover crop that will be sown in 2025 may influence that of each of the cover crop treatments.

Effect of allelopathic cover crop treatments on individual weed species

Weeds that were more prominent over the course of three months are in decreasing order: Wild buckwheat (Polygonum convolvulus L.), Hemp nettle (Galeopsis tetrahit L.), Stinkweed (Thlaspi arvense L.) and Rough cinquefoil (Potentilla norvegica L.) in Fort Kent, whereas Wild buckwheat, Redroot pigweed (Amaranthus retroflexus L.), Lambsquarters (Chenopodium album L.) and Canada thistle (Cirsium arvense L.) were more ubiquitious across the trial in St. Paul. Figure 1 shows the number of weeds individuals that were counted over time in all treatments. Averaging number of weed individuals on both sites it was found that the most prominent weeds were Wild buckwheat, Hemp nettle, Lambs quarters and Redroot pigweed. All weed individuals from these species were the same across treatments (Table 3). Of all these weeds, lamb's quarters individuals were found to be the same across all months in the growing season (Table 3). Figure 1 shows weed individuals for each of these species changed over the course of three months.

Table 3. P values obtained from analysis of variance of weed individuals counted in allelopathic cover crop treatments such as annual ryegrass, hairy vetch, rye and sunflower and intercrops between each these cover crops, counted three times during the growing season of 2024 in Fort Kent and in St. Paul Alberta

Effect	Wild buckwheat	Hemp nettle	Lamb's quarters	Redroot pigweed
cover crop treatment	0.41	0.99	0.06	0.16
month in the growing season	$<1.00 \times 10^{-4}$	2.00×10^{-4}	0.26	2.0010^{-4}
Cover crop treatment X Month in the growing season	0.34	0.19	0.91	0.03

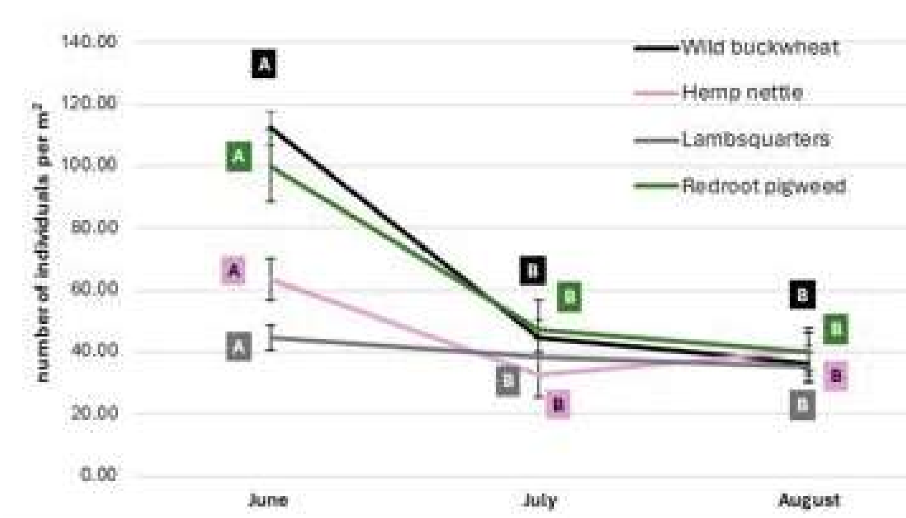
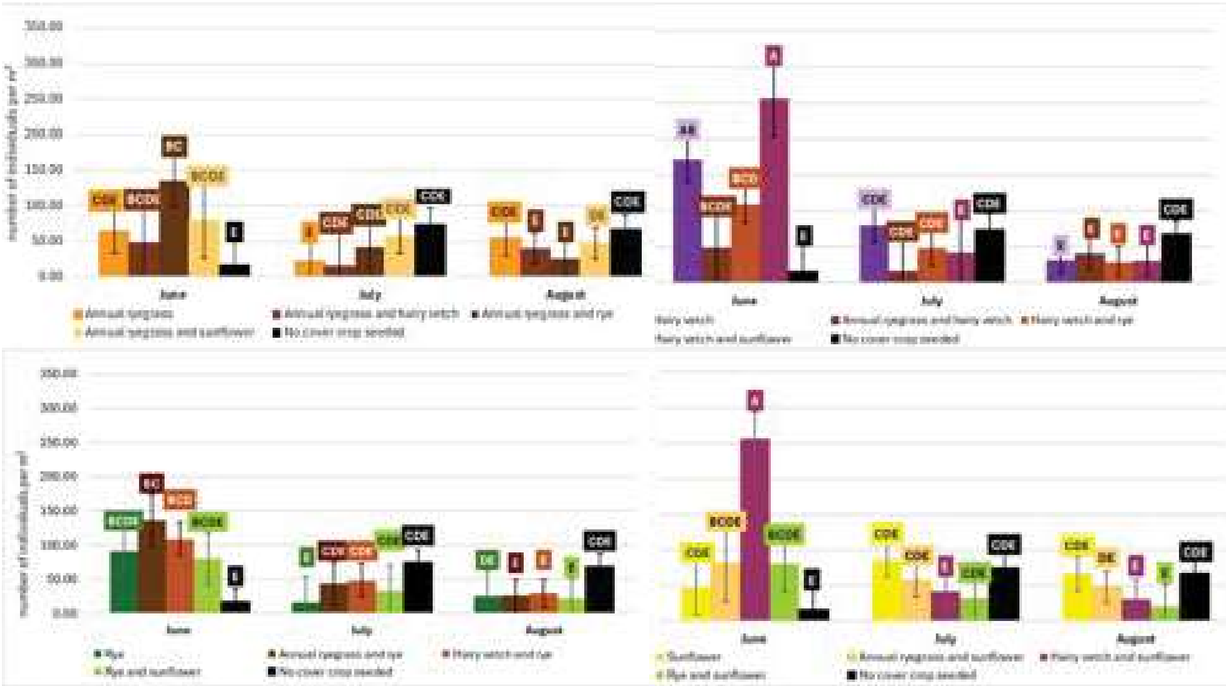


Figure 1. Number of weeds per m2 found in allelopathic treatments at three separate times during the growing season. Different letters of the same color show significance across three different measurements over the growing season (P<0.05, N=88)

Effect of allelopathic cover crop treatments on individual weed species

Figure 1 shows that all crops were effectively suppressed by the cover crop treatments by the end of the growing season. This shows that the allelopathic cover crop treatments sown are effective alternatives to suppress these weed species. Thereby, chemical management under these cover crop treatments can be delayed the following season, should a cash crop is considered to be included in the crop rotation.

Red root pigweed did show interaction effects from the allelopathic cover crop treatments over the repeated measures taken in the growing season (Figure 2-5). Redroot pigweed individuals in annual ryegrass + rye intercrop (Figure 2), hairy vetch, hairy vetch +rye and hairy vetch+ sunflower were more numerous in June compared to the control treatment. However, Redroot pigweed individuals overall showed no difference across cover crop treatments in July and August in comparison to the control (Figure 2-5).



Presence of Redroot pigweed (Amaranthus retroflexus L.) in (2) annual ryegrass (3) hairy vetch (4) rye and (5) sunflower stands sown either in monocrop or intercropped with aforementioned cover crops

In conclusion:

- Land equivalent ratio (LER) was greater in mixtures of sunflower + hairy vetch and sunflower + annual ryegrass. However actual yield loss shows that sunflower + hairy vetch and sunflower + rye have are disadvantageous. As such, sunflower stands are scarcer under these mixtures. If forage value is considered then annual ryegrass + sunflower are recommended as their AYL was the greatest among all cover crop treatments tested.
- Weed suppression is possible if a cover crop or better yet a cover crop intercrop is seeded compared to no cover crop in the ground. This means that chemical weed management can be reduced with inclusion of a cover crop and thus, reduce economical inputs
- So far, it has been shown that rye is the best monocrop and intercrop to suppress weeds are rye and annual ryegrass + rye respectively

Thank you for your support on this project: