Soil-applied Pre-Emergent Herbicides for established crop (IS00390.21-MT02):

Summary: The trial, conducted in 2021 and 2022, evaluated four pre-emergent herbicides that are not yet labelled for Haskap (Alion, Matrix, Princep, and Sinbar) in comparison with a currently registered pre-emergent (Casoron) and hand-weeded and untreated controls. Each of the herbicides were applied at two (low and high) rates. The trial was conducted at a commercial Haskap farm in SW Montana. No crop injury was observed.

In the first year, weed pressure was high with an average of 72 weeds m^{-2} in the untreated controls. Early season weed communities were dominated by prostrate knotweed and perennial grass (i.e. quackgrass). All pre-emergent herbicides reduced knot weed densities. High rates of Princep and either rate of Sinbar generally provided better control than Casoron. High rates of Sinbar and Matrix provided some control of quackgrass. At harvest, low rates of Alion, Casoron, and high rates of Matrix did not reduce weed biomass relative to the untreated controls. When averaged across sampling dates, most herbicides and associated rates reduced weed densities to a similar degree. Low rates of Princep and Matrix did not reduce weed densities relative to the untreated controls. High rates of Princep had almost no weed biomass at harvest. Yields were low (this was the first harvest year) and similar among treatments.

In the second year, weed pressure was much lower in weed counts in the untreated controls than the first year (<3 weeds m^{-2}). Weed community was dominated by quackgrass, prostrate knotweed, Kochia, perennial broadleaf weeds (mostly Canada thistle). Despite the low weed densities, most pre-emergent treatments reduced total weed densities relative to the untreated controls. Weed biomass in the untreated controls at harvest (219.1 g m^{-2}) was similar to year one (284.2 g m^{-2}) and provided more information on the efficacy of the treatments. Alion at either rate, while eliminating broadleaf weeds, had similar weed biomass to the controls due to high quackgrass biomass. All other treatments reduced total weed biomass compared to the untreated controls. All treatments provided good control of annual and perennial broadleaf weeds. Matrix at both rates, and Princep and Sinbar at higher rates reduced quackgrass biomass relative to the Alion treatments. These treatments also reduced quackgrass cover relative to the untreated controls at some sampling dates. Matrix applied at the higher rate (4 qt ac^{-1}) was the only treatment that provided season long reductions in quackgrass cover and reduced quackgrass biomass compared to the controls. Yields averaged 1.0 kg $plant^{-1}$ and were similar among treatments.

Materials and Methods:

This field trial took place at the Aspen Grove Berry Farm in Corvallis, MT (46.3274° N, 114.0841° W). The site was planted in 2019 with containerized one-year old *Lonicera caerulea* cultivars ‘Honeybee’ and ‘Boreal Beast’. The site has row and plant spacing of 3m and 1m respectively. Rows are oriented North – South on a <1% slope at an elevation of 1058m. The soil is in the Hamilton-Overwhich complex series which consists of deep silt-loam and loam.

The temperature, precipitation and weekly irrigation data during the trial period are summarized in Table 1. The spring was cooler than normal delaying the emergence of summer annual weeds.

The trial consisted of eleven treatments – a weed free (hand-weeded) treatment, an untreated control, and nine pre-emergent herbicide treatments. The products evaluated were Casaron 4G at one product rate as well as Alion, Sindbar WDG, Princep 4L and Matrix SG each at two different product rates (Table 3). Applications were made on March 12, 2022, while the haskap plants were in winter dormancy. Herbicide applications were made using a CO2 plot sprayer at a rate of 23.1 gallons per acre. Treatments were applied to create a 1.5 meter weed-free strip directly under the plant row. Treatments were assigned using a Randomized Complete Block Design. Each treatment had four replications; each replicate consisted of 6 adjacent honeyberry plants within a row.

To determine treatment effects on weed populations weed density (weeds m^{-2}) was recorded for each plot on four different sampling dates (Table 2.) during the growing season. Weed density was determined by counting the total number of weeds within a .18 m^2 sampling frame. The frame was placed at 3-4 random locations within each plot on each sampling date. To understand treatment effects on the weed community species and functional group were also recorded for each weed in the density samples.

Total above ground weed biomass (g m^{-2}) was recorded for each plot at harvest. Biomass was collected in a .18 m^2 sampling frame at 3 random locations within each plot. All of the weeds within the sampling frames were collected and the above ground biomass was weighed after samples had dried to a constant weight.

Plants in each treatment were also monitored for herbicide damage. No herbicide injury was observed.

Analysis:

Weed density data were analyzed with repeated measure ANOVA's for each species or functional group. All of the density data were square-root-transformed to improve the fit of the models. There was one significant outlier in weed density data in one of the Matrix 2 plots with extremely high densities of prostrate knotweed. These high densities only occurred in 1 of the 4 subsamples in this plot that were place in a small patch of dense weed seedlings. Given that this was a significant outlier and could represent an untreated area (skip in application) the subsample with extremely high knotweed densities was removed prior to analysis. Weed biomass was analyzed separately in one-way ANOVA's by the same groups. These data were also square-root transformed to meet the assumptions of the model. If ANOVA results indicated significant differences among treatments, LSD tests were used for post-hoc means comparison. The relationship between total weed biomass and yield was analyzed with a simple linear regression. Yield data was also analyzed in a two-way ANOVA by block and treatment.

Table 1. Meteorological and irrigation data April 1 – August 31 2022

Parameter	Month				
	April	May	June	July	August
Mean Temperature (°C)	2.8	9.4	15	20.6	21.1
Precipitation (mm)	20.32	35.56	33.02	7.62	10.16
Irrigation (L $plant^{-1}$ $week^{-1}$)	11.4	11.4	11.4	13.3	13.3

Table 2. 2022 sampling dates

Date	Sampling date
April 8	SD1
April 25	SD2
May 10	SD3
June 29	SD4

Table 3. Weed management treatments

Treatment	Product(s)[1]	Active ingredient (AI)	Product rate ha^{-1}	AI rate (kg ha^{-1})
WF	Hand weeded	N/A	N/A	N/A
Cntrl	Untreated	N/A	N/A	N/A
Ali3.5	Alion	indaziflam	.26 L	0.05
Ali7.0	Alion	indaziflam	.51 L	0.101
Sin1	Sindbar WDG	terbacil	1.12 kg	0.897
Sin2	Sindbar WDG	terbacil	2.24 kg	1.793
Pri2	Princep 4L	simazine	4.68 L	2.242
Pri4	Princep 4L	simazine	9.35 L	4.483
Matrix4	Matrix SG	rimsulfuron	0.58 L	0.139
Matrix2	Matrix SG	rimsulfuron	0.29 L	0.069
Cas	Casaron 4G	Dichlobenil	112.08 kg	4.483

Results:

Table 4. Mean weed density (weeds m^{-2}) of untreated control

Sampling day			
SD1	SD2	SD3	SD4
1	1.2	0.3	2.9

Table 5: Common weed species and functional groups analyzed in this trial

Functional Group	Common name	Scientific name
Rare annual broadleaf	Tumble mustard	*Sisymbium altissiumum*
	Purslane	*Portulaca oleraceae*
	Field pennycress	*Thlaspi arvense*
	Shephard's purse	*Casella bursa-pastoris*
Perennial Broadleaf	Canada thistle	*Cirsium arvense*
	Bladder campion	*Silene vulgaris*
	Dandelion	*Taraxacum officinale*
	Clover	*Trifolium sp.*
	Quack grass	*Elymus repens*
	Kochia	***Bassia scoparia***
	Prostrate knotweed	***Plygonum aviculare***

Weed community

Weed density was generally low, even in the untreated controls (Table 4). Table 5 summarizes the functional groups and species of weeds found in this trial. The relative abundance of weeds in this study was made up of rare annual broadleaf weeds (24%), perennial broadleaf weeds (21%), prostrate knotweed (21%), Kochia (20%), and Lambsquarter (9%). The relative abundance of weeds by biomass at harvest was dominated by quackgrass (64%), perennial broadleaf weeds (17%), and Kochia (13%). Quackgrass was not counted in the density samples but was counted independently as percent quackgrass cover.

Table 6. Results of ANOVA on weed densities across sampling dates for weed species and functional groups.

Source	df	Total weed densities	Total annual Broadleaf	Perennial broadleaf	Kochia	Prostrate knotweed	Rare annual broadleaf
Block	3						
Whole Plot							
Treatment	10	***	**	*	***	NS	***
Error	30						
Split Plot							
Sampling Date	3	NS	*	**	***	**	NS
SDxTMNT	30	**	*	***	***	NS	NS
error	99						

NS=Not significant, p>0.05,*=p<0.05, **=p<0.01, ***=p<0.001

Total weed density

Treatment was a significant predictor of total weed density across sampling dates and effects of treatments varied by sampling date (Table 6). Averaged across sampling dates, the treatments of Ali3.5, Pri2, Sin1, Cas, and Ali7.0 all significantly reduced weed density compared to the untreated control (Table 7). The remainder of the treatments including the untreated controls had relatively low weed densities (<3 weeds per m^2), but were similar to the untreated controls. In early season sampling dates (SD1 and SD2) nearly all treatments reduced weed densities relative to the controls, with the exceptions of Matrix2 and Sinbar 1. Weed densities were low in the untreated controls in the third sampling date and all herbicide treatments were similar to those controls. At the final sampling date, all of the treatments significantly reduced the number of weed present compared to the untreated control (Table 8).

Table 7. Total weed density across sampling dates

Treatment	weeds m^{-2}	
CNTRL	1.4	ab
Matrix2	0.5	b
Matrix4	0.3	bc
Sin2	0.2	bc
Pri4	0.2	bc
WF	0.2	bc
Ali3.5	0.1	c
Pri2	0.1	c
Sin1	0.1	c
Cas	0	c
Ali7.0	0	c

means with different letters differed significantly (Fisher LSD, α=0.05)

Table 8. Mean total weed densities (weeds m^{-2}) by treatment and sampling dates.

	Sampling Date							
Treatment	SD1		SD2		SD3		SD4	
Ali3.5	**0**	f	**0.3**	c-f	0.1	ef	**0**	f
Ali7.0	**0**	f	**0**	f	0	f	**0**	f
Cas	**0.1**	ef	**0**	f	0	f	**0**	f
CNTRL	1.0	bcd	1.2	b	0.3	c-f	2.9	a
Matrix4	**0.1**	ef	**0.2**	def	0.9	b-e	**0.1**	ef
Matrix2	0.2	c-f	0.7	bcd	0.8	b-e	**0.5**	c-f
Pri2	**0.1**	ef	**0**	f	0.1	ef	**0**	f
Pri4	**0**	f	**0.1**	ef	0.1	ef	**0.6**	b-f
Sin1	**0.1**	ef	**0.1**	ef	0	f	**0**	f
Sin2	**0.1**	ef	0.4	b-e	0.2	c-f	**0**	f
WF	**0**	f	**0**	f	0	f	**0.9**	bc

means with different letters differed significantly (Fisher LSD, α=0.05)

Total annual broadleaf

All of the treatments significantly reduced the annual broadleaf weed density compared to the control and effects varied by sampling date (Table 6). Averaged across sampling dates, all herbicide treatments reduced densities of annual broadleaf weeds (Table 9). Early in the season (SD1) Matrix at either rate did not provide significant weed reduction relative to the untreated controls. By the second and final sampling date significant reductions in the annual broadleaf weed densities could be seen in all treatments (Table 10).

Table 9. Total annual broadleaf weed density across sampling dates

Treatment	weeds m^{-2}	
CNTRL	1	a
Matrix2	0.4	b
Matrix4	0.3	bc
WF	0.2	bc
Pri4	0.2	bc
Sin2	0.1	bc
Ali3.5	0.02	bc
Pri2	0.02	bc
Sin1	0.02	bc
Ali7.0	0	c
Cas	0	c

means with different letters differed significantly (Fisher LSD, α=0.05)

Table 10. Mean total annual broadleaf weed densities (weeds m^{-2}) by treatment and sampling dates.

	Sampling Date							
Treatment	SD1		SD2		SD3		SD4	
Ali3.5	0	e	0	e	0.1	de	0	e
Ali7.0	0	e	0	e	0	e	0	e
Cas	0	e	0	e	0	e	0	e
CNTRL	0.6	bcd	1.0	b	0.3	b-e	2.1	a
Matrix4	0.1	de	0.2	cde	0.8	bcd	0.1	de
Matrix2	0.1	de	0.3	cde	0.8	bc	0.5	cde
Pri2	0	e	0	e	0.1	de	0	e
Pri4	0	e	0	e	0.1	de	0.6	bcd
Sin1	0	e	0.1	de	0	e	0	e
Sin2	0	e	0.2	cde	0.1	de	0	e
WF	0	e	0	e	0	e	0.9	b

means with different letters differed significantly (Fisher LSD, α=0.05)

Rare annual broadleaf

Rare annual broadleaf weed densities were significantly reduced by all treatments compared to the control and these effects were consistent across sampling dates (Tables 6 and 11).

Table 11. Rare annual broadleaf weed density across sampling dates

Treatment	weeds m^{-2}	
CNTRL	0.5	a
WF	0.08	b
Matrix2	0.08	b
Matrix4	0.03	b
Pri4	0	b
Sin1	0.03	b
Ali3.5	0	b
Ali7.0	0	b
Cas	0	b
Pri2	0	b
Sin2	0	b

means with different letters differed significantly (Fisher LSD, α=0.05)

Prostrate Knotweed

No treatment significantly reduced the density of prostrate knotweed compared to the control. The density was similar among treatments and generally low.

Kochia

Kochia density were affected by treatments and these effects varied across sampling dates (Table 6). Averaged across sampling dates all treatments reduced kochia densities relative to the untreated controls (Table 12). The interaction between treatment and sampling date is driven by the late season emergence of this weed species. Kochia did not appear in any experimental plot until the third sampling date. On this date the density of this weed was very low and no treatment significantly reduced kochia density relative to the controls. By the final sampling date all treatments significantly reduced the density of Kochia compared to the control (Table 13).

Table 12. Mean Kochia weed density across sampling dates

Treatment	weeds m^{-2}	
CNTRL	0.36	a
Matrix2	0.14	b
Pri4	0.06	bc
WF	0.06	bc
Ali3.5	0	c
Ali7.0	0	c
Cas	0	c
Matrix4	0	c
Pri2	0	c
Sin1	0	c
Sin2	0	c

means with different letters differed significantly (Fisher LSD, α=0.05)

Table 13. Mean Kochia weed densities (weeds m^{-2}) by treatment and sampling dates.

	Sampling Date							
Treatment	SD1		SD2		SD3		SD4	
Ali3.5	0	c	0	c	0	c	0	c
Ali7.0	0	c	0	c	0	c	0	c
Cas	0	c	0	c	0	c	0	c
CNTRL	0	c	0	c	0	c	1.5	a
Matrix4	0	c	0	c	0	c	0	c
Matrix2	0	c	0	c	0.2	bc	0.3	b
Pri2	0	c	0	c	0	c	0	c
Pri4	0	c	0	c	0.1	bc	0.1	bc
Sin1	0	c	0	c	0	c	0	c
Sin2	0	c	0	c	0	c	0	c
WF	0	c	0	c	0	c	0.2	b

means with different letters differed significantly (Fisher LSD, α=0.05)

Perennial broadleaf weeds

The mean perennial broadleaf weed density was significantly reduced by all treatments relative to the control (Table 14). As seen in Table 16 on both the first and third sampling dates perennial broadleaf weeds were found in very low densities across all treatments including the control. On the final sampling date every treatment was effective at reducing the density of perennial broadleaf weeds (Table 16).

Table 14. Perennial broadleaf weed density across sampling dates

Treatment	weeds m^{-2}	
CNTRL	0.28	a
Matrix2	0.11	b
Sin2	0.08	b
Ali3.5	0.08	b
Matrix4	0.03	b
Pri4	0.03	b
Sin1	0.03	b
Ali7.0	0	b
Cas	0	b
Pri2	0	b
WF	0	b

means with different letters differed significantly (Fisher LSD, α=0.05)

Table 15. Mean perennial broadleaf weed densities (weeds m^{-2}) by treatment and sampling dates.

	Sampling Date							
Treatment	SD1		SD2		SD3		SD4	
Ali3.5	0	d	0.3	b	0	d	0	d
Ali7.0	0	d	0	d	0	d	0	d
Cas	0	d	0	d	0	d	0	d
CNTRL	0.1	cd	0.2	bc	0	d	0.8	a
Matrix4	0	d	0	d	0.1	cd	0	d
Matrix2	0.1	cd	0.3	b	0	d	0	d
Pri2	0	d	0	d	0	d	0	d
Pri4	0	d	0.1	cd	0	d	0	d
Sin1	0.1	cd	0	d	0	d	0	d
Sin2	0.1	cd	0.2	bc	0	d	0	d
WF	0	d	0	d	0	d	0	d

means with different letters differed significantly (Fisher LSD, α=0.05)

Weed Biomass at Harvest

The above ground weed biomass was significantly affected by treatments in all species and functional groups other than for prostrate knotweed and rare annual broadleaf weeds (Table 16). Alion was the only product tested whose treatments did not significantly reduce total weed biomass compared to the control (Table 17). Alion provided excellent control of annual weeds but had quackgrass biomass that was similar to the controls and greater than many other herbicide treatments. The above ground biomasses of total annual broadleaf weeds, perennial broadleaf weeds and Kochia were significantly reduced by all treatments in this trial (Table 17).

The Quackgrass biomass was significantly reduced only by the Matrix4 treatment, all other treatments were ineffective in reducing the biomass of this weed (Table 17).

Table 16. Results of ANOVA on biomass for weed species and functional groups.

Source	df	Total weed biomass	Total annual Broadleaf	Quack grass	Perennial broadleaf	Kochia	Prostrate knotweed	Rare annual broadleaf
Block	3	NS	NS	NS	NS	NS	NS	NS
Treatment	10	**	**	**	***	***	NS	NS
Error	30							

NS=Not significant, p>0.05,*=p<0.05, **=p<0.01, ***=p<0.001

Table 17. Mean total biomass (g m^{-2}) by treatment

Treatment	Total weed		Total annual broadleaf		Perennial broadleaf		Kochia		Quackgrass	
Ali3.5	73.5	abc	**0**	b	**0**	b	**0**	b	73.5	a
Ali7.0	96.8	ab	**0**	b	**0**	b	**0**	b	96.8	a
Cas	**58.1**	bcd	**5.7**	b	**18.7**	b	**0**	b	33.8	abc
CNTRL	219.1	a	95.5	a	90.9	a	73.6	a	32.8	abc
Matrix4	**11.3**	d	**6.9**	b	**0**	b	**0**	b	**4.4**	d
Matrix2	**28.8**	bcd	**8.4**	b	**0**	b	**8.1**	b	20.5	bcd
Pri2	**45.4**	bcd	**0**	b	**0**	b	**0**	b	45.4	ab
Pri4	**8.5**	d	**2.5**	b	**0**	b	**0**	b	6.0	cd
Sin1	**65.8**	bcd	**0**	b	**1.9**	b	**0**	b	64.0	ab
Sin2	**33.5**	cd	**0**	b	**0**	b	**0**	b	33.5	bcd
WF	**10.3**	d	**3.3**	b	**0**	b	**1.4**	b	7	cd

Within columns means with different letters differed significantly (Fisher LSD, α=0.05) and the bolded means were less than the control.

Quackgrass cover

Quackgrass cover was significantly affected by treatment (Treatment, $F_{10,30} = 9.38$, $p<0.001$) and treatment effects on cover varied by sampling date (Treatment x SD, $F_{30,99}=1.69$, $p<0.05$). Averaged across sampling dates, both of the Matrix treatments and the high rates of Princep and the Sinbar significantly reduced Quackgrass cover in this trial relative to the untreated control (Table 18). Matrix4 was the only product treatment that significantly reduced Quackgrass cover across all sampling dates (Table 19).

Table 18. Quack grass cover (%) by treatment

Treatment	Percent cover	
Ali7.0	13.3	a
Sin1	11.6	ab
Ali3.5	7.8	ab
CNTRL	7.7	ab
Cas	7.2	ab
Pri2	6.4	b
Pri4	2.6	c
Sin2	2.9	c
Matrix2	2.4	cd
Matrix4	1.4	cd
WF	0.7	d

means with different letters differed significantly (Fisher LSD, α=0.05)

Table 19. Mean quackgrass cover (%) by treatment and sampling date

	Sampling Date							
Treatment	SD1		SD2		SD3		SD4	
Ali3.5	5.6	f-l	6	d-j	6.9	c-i	12.6	abc
Ali7.0	9.5	b-g	11.1	a-e	14.4	ab	18.1	a
Cas	5.5	e-k	5.2	f-m	12.2	a-d	6.1	c-j
CNTRL	4.8	g-m	6.8	d-j	7.4	b-i	11.8	a-f
Matrix4	**1.3**	op	**0.8**	op	**2.4**	op	**1.3**	op
Matrix2	1.6	mno	2.8	j-o	**3.3**	mno	**1.9**	mno
Pri2	3.2	i-o	6.1	d-j	6.8	c-i	9.5	b-g
Pri4	1.9	l-o	2.9	i-o	4.4	h-n	**1**	nop
Sin1	8.6	b-h	11.7	a-d	*18.8*	a	7.1	d-j
Sin2	**0.9**	op	**1.9**	k-o	7.2	b-i	**1.5**	op
WF	**0**	p	**0**	p	**0**	p	**2.8**	no

means with different letters differed significantly (Fisher LSD, α=0.05)

Yield

Haskap yields averaged 1.0 kg plant^{-1} and were similar among treatments. Yields were similar across treatments ($F_{10,32} = 1.39$, p =.25). Across the plots, the total weed biomass at harvest was negatively correlated with yield. As the total weed biomass increased the yield per plant decreased (simple regression, slope = -0.0013, SE = 0.0005, t= -2.51, DF= 42, p= 0.016).