Herbicide application with a pulse width modulation sprayer for leafy spurge and Canada thistle control. Rodney G. Lym. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58108-6050). Pulse Width Modulation (PWM) technology has been developed to improve precision application of pesticides. PWM involves rapidly switching an electrically-actuated solenoid on and off (duty cycle) in order to control the flow rate of the nozzle. This cycling takes place so quickly the flow appears to be constant and the coverage remains reasonably uniform. Controlling flow rate by adjusting duty cycle and cycling frequency of an electric nozzle while maintaining a constant pressure provides advantages over controlling flow by adjusting pressure. Normally, increasing spray pressure results in increased flow rate. However, increased pressure also changes the spray angle and droplet size which may result in increased spray particle drift. PWM flow control provides an extremely wide range of flow rates from a single nozzle, maintaining a consistent spray angle and droplet size without adjusting pressure.

The PWM technology has yet to be adapted for weed control in pasture, rangelands, and wildlands. Use of a PWM sprayer would allow both drift reduction and more precise application at the variable speeds required when driving in uneven and rugged terrain. The PWM sprayer will reduce the duty cycle (percent of time a nozzle is open) when the applicator slowed to avoid obstacles and then increase the cycle as the speed increased. The pressure and droplet size remain the same, so application rate is unaffected by changes in speed.

Five experiments were established to evaluate leafy spurge and Canada thistle control using the PWM sprayer. The first series of studies evaluated the effect of droplet size on weed control. Various nozzles and pressures were used with the PWM sprayer to apply herbicides so that the spray pattern consisted of 150, 300, 450, 600, 750, or 900 micron droplets at 10 gpa. Application speed was 10 mph and a NIS at 0.25% was included with all treatments(Induce). A tractor mounted boom sprayer with XR8002 nozzles calibrated to apply treatments at 17 gpa and 35 psi was included as the standard. Picloram plus 2,4-D at 4 + 16 oz/A was applied to leafy spurge while aminopyralid at 1.25 oz/A was applied for Canada thistle control. Separate spring or fall studies were established on June 23, 2016 or September 14, 2016 for each weed species. Leafy spurge was in the true flower or fall-regrowth stage, at the time of the spring or fall treatment, respectively. Canada thistle was in the rosette to bolting stage when the spring treatments were applied and in the rosette growth stage in the fall. Plots were 15 by 40 feet and treatments were replicated three times in all studies.

Leafy spurge and Canada thistle control was similar when herbicides were applied with the PWM system in the spring compared to a standard boom sprayer at all droplet sizes except 150 microns (Table 1). Leafy spurge control averaged 96% 1 month after treatment (MAT) with all droplet sizes except 150 microns which only averaged 60%. *Aphthona* spp. (leafy spurge biological control agents) established in the western side of the research plots during the summer resulting in better than expected control.

Canada thistle control averaged 98% 12 MAT with all spring applied treatments except when application was made with nozzles that applied primarily 150 micron droplets which only

averaged 63% (Table 2). Control averaged 96% 14 MAT regardless of droplet size with the exception of the 150 micron droplet treatment which declined to 55%.

Leafy spurge control averaged 92% 9 MAT when picloram plus 2,4-D was applied in the fall with the PWM sprayer using droplet sizes of 600 to 900 microns compared to 89% with a standard boom sprayer equipped with XR8002 nozzles (Table 3). Treatments applied using droplet sizes of 450 microns or less did not provide satisfactory leafy spurge control. Fall Canada thistle control with aminopyralid averaged 100% 9 MAT when droplet size was 450 microns or greater (Table 4). Canada thistle control averaged 95 and 10% when aminopyralid was applied using 300 and 150 micron droplets, respectively.

The fifth study evaluated leafy spurge control with quinclorac applied at 12 oz/A with the PWM sprayer at three application speeds. The droplet size was held constant at 550 microns and 10 gpa for all applications with duty cycles of 30, 60, and 90% at 5, 10 and 15 mph speeds, respectively. The study was established on the Sheyenne National Grassland near Anselm, ND on June 20, 2017 when leafy spurge was in the flowering growth stage. Plots were 30 by 150 feet. Leafy spurge control averaged 95% 2 MAT regardless of application speed (Table 5).

In summary, herbicides applied with the PWM system provided similar leafy spurge and Canada thistle control compared to traditional boom sprayer with XR8002 nozzles as long as the average droplet size exceeded 150 microns. The only exception was the fall treatment of leafy spurge when control was best with droplet sizes of 600 microns or more. Initial results from a single study found no difference in leafy spurge control with quinclorac at application speeds from 5 to 15 mph. The PWM sprayer can be used to apply herbicides in pasture and rangeland at a variety of travel speeds while maintaining medium sized spray droplets resulting in reduced drift and uniform coverage.

Table 1. Leafy spurge control with picloram plus 2,4-D applied on June 23, 2016 with a pulse width modulation (PWM) sprayer using various nozzles compared to a tractor mounted boom sprayer at Fargo, ND.

Treatment				Rate	Months after treatment. 1	2	12[a]	14[a]
		Nozzle	Droplet	oz/A	% control			
Picloram + 2,4-D + NIS[b]	PWM	ER110015	150	4 + 16 + 0.25%	60	44	83	50
Picloram + 2,4-D + NIS	PWM	SR11002	300	4 + 16 + 0.25%	95	56	62	39
Picloram + 2,4-D + NIS	PWM	MR11004	450	4 + 16 + 0.25%	97	71	70	28
Picloram + 2,4-D + NIS	PWM	DR11005	600	4 + 16 + 0.25%	96	71	50	55
Picloram + 2,4-D + NIS	PWM	DR11006	750	4 + 16 + 0.25%	95	47	53	32
Picloram + 2,4-D + NIS	PWM	UR11006	900	4 + 16 + 0.25%	96	72	93	42
Picloram + 2,4-D + NIS	CO_2	XR8002	Medium[c]	4 + 16 + 0.25%	98	51	56	30
LSD (0.05)					17	NS	NS	NS

[a]*Aphthona* spp. flea beetles established in western half of plot area resulting in much better leafy spurge control than expected in those plots and increased plot to plot variation.

[b]Surfactant at 0.25% applied with all treatments - Induce by Helena Chemical Co., 225 Schilling Blvd, Collierville, TN 38017.

[c]Medium-size droplet range is 281 - 429 microns.

Table 2. Canada thistle control with aminopyralid applied on June 23, 2016 with a pulse width modulation (PWM) sprayer using various nozzles compared to a tractor mounted boom sprayer at Fargo, ND.

Treatment				Rate	Months after treatment 1	2	12	14
		Nozzle	Droplet	oz/A	% control			
Aminopyralid + NIS[a]	PWM	ER110015	150	1.25 + 0.25%	75	83	63	55
Aminopyralid + NIS	PWM	SR11002	300	1.25 + 0.25%	89	99	98	99
Aminopyralid + NIS	PWM	MR11004	450	1.25 + 0.25%	92	100	99	99
Aminopyralid + NIS	PWM	DR11005	600	1.25 + 0.25%	98	100	96	91
Aminopyralid + NIS	PWM	DR11006	750	1.25 + 0.25%	96	100	98	98
Aminopyralid + NIS	PWM	UR11006	900	1.25 + 0.25%	95	99	100	95
Aminopyralid + NIS	CO_2	XR8002	Medium[b]	1.25 + 0.25%	94	99	94	96
LSD (0.05)					11	12	25	29

[a]Surfactant at 0.25% applied with all treatments - Induce by Helena Chemical Co., 225 Schilling Blvd, Collierville, TN 38017.
[b]Medium-size droplet range is 281 - 429 microns.

Table 3. Leafy spurge control with picloram plus 2,4-D applied on September 14, 2016 with a pulse width modulation (PWM) sprayer using various nozzles compared to a tractor mounted boom sprayer at Fargo, ND.

Treatment		Nozzle	Droplet	Rate	Months after treatment 9	12
				oz/A	% control	
Picloram + 2,4-D + NIS[a]	PWM	ER80015	150	8 + 16 + 0.25%	5	0
Picloram + 2,4-D + NIS	PWM	SR8002	300	8 + 16 + 0.25%	5	5
Picloram + 2,4-D + NIS	PWM	MR8004	450	8 + 16 + 0.25%	62	28
Picloram + 2,4-D + NIS	PWM	DR8005	600	8 + 16 + 0.25%	90	30
Picloram + 2,4-D + NIS	PWM	DR8006	750	8 + 16 + 0.25%	93	48
Picloram + 2,4-D + NIS	PWM	UR8006	900	8 + 16 + 0.25%	93	52
Picloram + 2,4-D + NIS	CO_2	XR8002	Medium[b]	8 + 16 + 0.25%	89	28
LSD (0.05)					28	25

[a]Surfactant at 0.25% applied with all treatments - Induce by Helena Chemical Co., 225 Schilling Blvd, Collierville, TN 38017.
[b]Medium-size droplet range is 281 - 429 microns applied with tractor sprayer.

Table 4. Canada thistle control with aminopyralid applied on September 14, 2016 with a pulse width modulation (PWM) sprayer using various nozzles compared to a tractor mounted boom sprayer at Fargo, ND.

Treatment		Nozzle	Droplet	Rate	Months after treatment 9	12
				—oz/A—	—% control—	
Aminopyralid + NIS[a]	PWM	ER80015	150	1.25 + 0.25%	10	8
Aminopyralid + NIS	PWM	SR8002	300	1.25 + 0.25%	95	92
Aminopyralid + NIS	PWM	MR8004	450	1.25 + 0.25%	100	100
Aminopyralid + NIS	PWM	DR8005	600	1.25 + 0.25%	99	99
Aminopyralid + NIS	PWM	DR8006	750	1.25 + 0.25%	100	98
Aminopyralid + NIS	PWM	UR8006	900	1.25 + 0.25%	100	98
Aminopyralid + NIS	CO_2	XR8002	Medium[b]	1.25 + 0.25%	100	97
LSD (0.05)					3	15

[a]Surfactant at 0.25% applied with all treatments - Induce by Helena Chemical Co., 225 Schilling Blvd, Collierville, TN 38017.
[b]Medium-size droplet range is 281 - 429 microns.

Table 5. Leafy spurge control with quinclorac applied on June 20, 2017 with a pulse width modulation (PWM) sprayer using compared to a tractor mounted boom sprayer at Fargo, ND.

Treatment/application speed	MPH[a]	Rate —oz/A—	Months after treatment 2 —% control—
Quinclorac + MSO[b]	5	12 + 1 pt	95
Quinclorac + MSO	10	12 + 1 pt	92
Quinclorac + MSO	15	12 + 1 pt	97
LSD (0.05)			NS

[a]Application speed in miles per hour with a Wilger DR11006 nozzle and an average of 550 micron droplet size applied at 10 gpa.
[b]MSO - methylated seed oil 13064 by Winfield United 4001 Lexington Ave. N., Arden Hills, MN 55126.