DEFOLIATION TIMING EFFECTS ON SPOTTED KNAPWEED SEED PRODUCTION AND VIABILITY

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BACKGROUND

Spotted knapweed (*Centaurea stoebe*) is a deeply taprooted, invasive perennial forb infesting millions of acres of native rangeland in the United States and Canada. It is currently documented to infest every U.S. state except Alaska, Texas, Oklahoma, and Mississippi and causes severe economic impacts. In Montana alone, >$42 million is lost annually to Montana's economy in direct and indirect costs associated with spotted knapweed. Spotted knapweed is capable of forming large monocultures, lowers plant diversity, decreases the abundance and diversity of native soil microbes, reduces livestock and wildlife forage, and increases surface water runoff and sediment yield.

Prescribed sheep grazing is a useful method of spotted knapweed control, especially when mechanical, cultural, biological, and chemical methods are restricted or constrained by environmental or economic concerns. However, spotted knapweed produces new, additional flowers before the end of the growing season after being defoliated during the bolting or flowering stages. It has not yet been determined if these new flowers produce viable seed. Because spotted knapweed is a prolific seed producer, optimizing the timing(s) of defoliation to reduce its viable seed production and input into the seedbank would improve the efficacy of prescribed sheep grazing for spotted knapweed control.

PURPOSE

The purpose of our research was to determine the appropriate timing(s) or combination(s) of timings of spotted knapweed defoliation to reduce its viable seed production.

SUMMARY OF FINDINGS

Spotted knapweed produced new buds and flowers after plants were clipped once, twice, or three times during summer. However, all clipping treatments reduced the number of buds/flowerheads present at the end of the growing season compared with no clipping. Clipped plants produced 73-98% fewer buds/flowerheads than unclipped plants (Table 1).

All clipping treatments also reduced seed production by spotted knapweed. The number of doughy, intermediate, and mature seeds, and the total number of seeds were all reduced by clipping. Clipping in June during the bolting stage reduced the total number of seeds 75-81%, whereas clipping at all other times or combinations of timings reduced the total number of seeds produced 98-100% (Table 2).

No doughy seeds were viable throughout the study. Clipping in June during the bolting stage reduced percent viability of intermediate seeds 57%, whereas clipping at all other timings or combinations of timings reduced percent viability of intermediate seeds 99% compared with no clipping (Table 3). All clipping treatments also reduced the percent viability of mature seeds. Clipping in June during the bolting stage reduced percent viability of mature seeds 23-58%, whereas clipping at all other timings or combinations of timings reduced percent viability of mature seeds 58-99.6% (Table 3).

The numbers of viable intermediate, mature, and total seeds were all reduced by clipping. Clipping in June during the bolting stage reduced the total number of viable seeds nearly 90% compared with no clipping (Table 4). Clipping in July during the late-bud/early-flower stage, clipping

in August during the full-flower stage, or clipping at any combination of timings reduced the total number of viable seeds almost 100% compared with no clipping (Table 4).

CONCLUSIONS

All defoliation treatments in our study reduced the number of viable seeds produced by spotted knapweed. Results indicate that viable seed production of spotted knapweed is most effectively suppressed by defoliation during the late-bud/early-flower or full-flower stages. These findings align favorably with results from studies that document sheep effectively removing buds and flowers of spotted knapweed at these stages of growth when prescriptively grazing within spotted knapweed infestations. Therefore, sheep grazing can be effectively applied in the late-bud/early-flowers stage or full-flower stage for spotted knapweed control.

APPLICATIONS

Results from this study can be used by Montana sheep producers who wish to use their sheep to graze spotted- infested rangeland on their own property or on other grazing lands. Knowing that grazing by sheep in the summer from the late-bud/early-flowers stage to full-flower stage will effectively reduce viable seed production can aid producers in planning grazing management strategies for spotted knapweed control.

Sheep do not need to be quarantined before moving to a new area if sheep graze spotted knapweed during the bolting or late-bud/early-flower stages, because spotted knapweed plants at these phenological stages do not contain viable seed. However, if sheep graze in the full-flower stage, some viable seeds may be present on plants that are in a more advanced growth stage. In this case, quarantining sheep in a corral for seven days to allow viable seeds to be excreted before moving the sheep to a new area is ideal.

Table 1. Number of buds/flowerheads (±SE) produced per spotted knapweed plant after defoliation at different timings and combinations of timings on foothill rangeland in western Montana.

Treatment	Year		Mean
	2006	2007	
	----------(Number per plant)----------		
Control	23.8 (3.4)a[4]	19.1 (3.4)a	21.3 (2.4)a
June[1]	7.8 (1.5)b	4.0 (0.7)b	5.9 (0.9)b
July[2]	8.2 (2.1)b	2.7 (1.0)bc	5.5 (1.3)b
August[3]	2.6 (0.6)c	1.9 (0.6)cd	2.3 (0.4)c
June+July	4.2 (2.2)c	2.2 (1.2)ce	3.3 (1.3)c
June+August	0.3 (0.2)d	0.3 (0.2)de	0.3 (0.1)d
July+August	1.9 (0.9)cd	1.4 (0.6)cd	1.7 (0.5)ce
June+July+August	0.3 (0.2)d	0.4 (0.2)de	0.4 (0.1)de

[1]Spotted knapweed in bolting stage.
[2]Spotted knapweed in late-bud/early-flower stage.
[3]Spotted knapweed in full-flower stage.
[4]Means within columns followed by the same letter are not different ($P > 0.05$).

Table 2. Number of doughy, intermediate, and mature spotted knapweed seeds (±SE) per plant produced after defoliation at different timings and combinations of timings on foothill rangeland in western Montana.

Seed Stage	Treatment	Year 2006	Year 2007	Mean
		----------(Number per plant)----------		
Doughy	Control	144.9 (30.4)a[4]	155.5 (28.2)a	150.5 (20.1)a
	June[1]	61.1 (16.9)b	34.2 (9.6)b	47.7 (9.9)b
	July[2]	13.5 (7.9)c	6.6 (2.9)c	10.1 (4.2)c
	August[3]	0c	0c	0d
	June+July	16.0 (13.8)c	1.6 (1.6)c	9.2 (7.3)cd
	June+August	0c	0c	0d
	July+August	0.3 (0.3)c	1.2 (1.2)c	0.8 (0.6)d
	June+July+August	0c	0c	0d
Intermediate	Control	20.4 (3.5)a	29.0 (6.9)a	24.9 (4.0)a
	June	6.9 (2.5)b	2.0 (0.5)b	4.5 (1.4)b
	July	3.3 (2.4)bc	1.3 (0.9)bc	2.3 (1.3)c
	August	0c	0c	0d
	June+July	1.3 (1.3)c	0c	0.7 (0.7)cd
	June+August	0c	0c	0cd
	July+August	0c	0c	0d
	June+July+August	0c	0c	0d
Mature	Control	196.9 (35.1)a	24.7 (6.3)a	106.3 (26.1)[5]
	June	22.6 (7.1)b	4.5 (2.6)b	13.6 (4.2)
	July	0.5 (0.5)c	1.9 (0.9) bc	1.2 (0.5)
	August	0c	0c	0
	June+July	0.1 (0.1)c	0c	0.1 (0.1)
	June+August	0c	0c	0
	July+August	0c	0c	0
	June+July+August	0c	0c	0
Total	Control	362.2 (61.8)a	209.2 (37.5)a	281.7 (38.7)[5]
	June	90.6 (22.5)b	40.7 (11.5)b	65.7 (13.6)
	July	17.3 (9.8)c	9.8 (4.4)c	13.6 (5.3)
	August	0c	0de	0
	June+July	17.4 (15.2)c	1.6 (1.6)cd	9.9 (8.1)
	June+August	0c	0de	0
	July+August	0.3 (0.3)c	1.2 (1.2)ce	0.8 (0.6)
	June+July+August	0c	0de	0

[1]Spotted knapweed in bolting stage.
[2]Spotted knapweed in late-bud/early-flower stage.
[3]Spotted knapweed in full-flower stage.
[4]Means in the same column within seed stage followed by the same letter are not different ($P > 0.05$).
[5]Treatment by year interaction ($P \leq 0.05$).

Table 3. Viability (%) of intermediate and mature spotted knapweed seeds (±SE) per plant produced after defoliation at different timings and combinations of timings on foothill rangeland in western Montana.

Seed Stage	Treatment	Year 2006	Year 2007	Mean
		----------(%)----------		
Intermediate	Control	25.0 (7.4)a[4]	44.8 (7.4)a	35.4 (5.6)a
	June[1]	13.5 (6.7)b	16.7 (10.2)b	15.1 (5.9)b
	July[2]	0c	6.0 (6.0)bc	3.0 (3.0)c
	August[3]	0c	0c	0c
	June+July	0c	0c	0c
	June+August	0c	0c	0c
	July+August	0c	0c	0c
	June+July+August	0c	0c	0c
Mature	Control	89.0 (2.0)a	89.0 (2.4)a	89.0 (1.5)[5]
	June	68.2 (12.0)b	35.1 (14.6)b	51.7 (10.0)
	July	2.0 (2.0)c	40.0 (16.3)b	21.0 (9.1)
	August	0c	0c	0
	June+July	0c	0c	0
	June+August	0c	0c	0
	July+August	0c	0c	0
	June+July+August	0c	0c	0

[1]Spotted knapweed in bolting stage.
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[3]Spotted knapweed in full-flower stage.
[4]Means in the same column within seed stage followed by the same letter are not different ($P > 0.05$).
[5]Treatment by year interaction ($P \leq 0.05$).

Table 4. Number of viable intermediate and mature spotted knapweed seeds (±SE) produced per plant after defoliation at different timings and combinations of timings on foothill rangeland in western Montana.

Seed Stage	Treatment	Year 2006	Year 2007	Mean
		----------(Number per plant)----------		
Intermediate	Control	6.1 (2.0)a[4]	10.4 (2.4)a	8.4 (1.6)[5]
	June[1]	1.4 (0.6)b	0.3 (0.2)b	0.9 (0.3)
	July[2]	0c	0.3 (0.3)b	0.2 (0.2)
	August[3]	0c	0b	0
	June+July	0c	0b	0
	June+August	0c	0b	0
	July+August	0c	0b	0
	June+July+August	0c	0b	0
Mature	Control	173.0 (30.3)a	21.0 (4.9)a	93.0 (22.8)[5]
	June	20.1 (6.7)b	3.5 (1.9)b	11.8 (3.9)
	July	0.1 (0.1)c	1.9 (0.9)bc	1.0 (0.5)
	August	0c	0c	0
	June+July	0c	0c	0
	June+August	0c	0c	0
	July+August	0c	0c	0
	June+July+August	0c	0c	0
Total	Control	179.1 (29.8)a	31.4 (5.7)a	101.4 (22.3)[5]
	June	21.5 (7.3)b	3.8 (1.8)b	12.7 (4.2)
	July	0.1 (0.1)c	2.2 (1.2)bc	1.2 (0.6)
	August	0c	0c	0
	June+July	0c	0c	0
	June+August	0c	0c	0
	July+August	0c	0c	0
	June+July+August	0c	0c	0

[1]Spotted knapweed in bolting stage.
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[3]Spotted knapweed in full-flower stage.
[4]Means in the same column within seed stage followed by the same letter are not different ($P > 0.05$).
[5]Treatment by year interaction ($P \leq 0.05$).