NON-CHEMICAL CONTROL OF PERENNIAL PEPPERWEED: USING EXTENDED PERIODS OF SOLARIZATION AND LIGHT EXCLUSION TO ERADICATE A PERENNIAL INVASIVE WEED

ERP 02D-P66 PROJECT REPORT

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Keywords: solarization, perennial pepperweed

1.0 Subtask 4.2 Introduction

This report summarizes the findings of Task 4.2: Effect of multi-year tarping on control of *Lepidium latifolium* of ERP-02D-P66.

1.1. Objective

The objective of this task was to test the eradication efficacy of tarping treatments on perennial pepperweed (*Lepidium latifolium*) at the Cosumnes River Preserve. We tested two tarping methods over a period of two growing seasons: a mow, disk, tarp method and a mow, tarp method.

2.0 Background

Perennial pepperweed (*Lepidium latifolium)*, a known invader of riparian habitats, is a dominate species along the edges of organic rice fields at the Cosumnes River Preserve. The extensive network of organic rice fields doubles as habitat for migratory birds, including the sandhill crane (*Grus canadensis*). Established perennial pepperweed patches in and adjacent to organic agricultural areas at the preserve are in close proximity to cars, humans, animals and water: all of which are considered dispersal agents for the species. With adequate source material and dispersal agents, pepperweed can spread to adjacent sensitive riparian habitat via viable seed or plant propagules during flood events. In our effort to control the expansion of pepperweed at the Cosumnes River Preserve, we tested the success of tarping as a non-chemical control method while monitoring non-target vegetation response. As tarping is reported to have moderate success in controlling perennial species, we hypothesized that by tarping existing populations for two consecutive growing seasons we could eradicate perennial pepperweed without herbicides.

2.1. Solarization

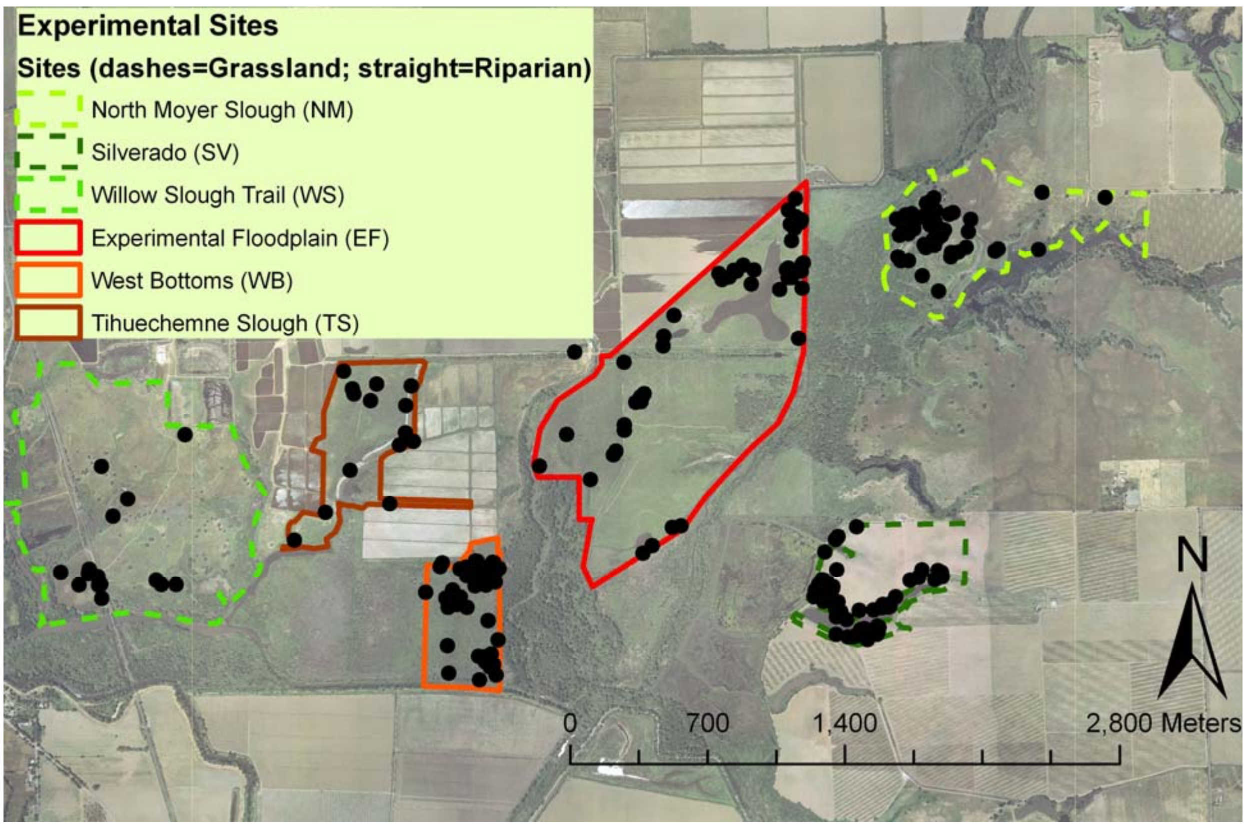
As organic agriculture becomes increasingly popular, there is a pervasive need to demonstrate and examine non-chemical weed control methods. Weed infestations in agricultural settings are associated with lower production and ultimately lower profits (Sauerborn 1989). While organic agriculture provides benefits for ecosystem functioning as a whole, weed species richness is generally higher (Ngouajio & McGiffin 2002). This can pose a risk to natural communities when and if competing demands, such as conventional and organic agricultural practices, co-occur with other land use management objectives, such as weed eradication and wildlife management.

A successful non-chemical control routine requires the integration of multiple environmental factors to prescribe the correct control methods for a specific agricultural field or region (Lundkvist et al. 2008). Tarping or solarization is becoming increasingly popular as a non-chemical control option (ex. Horowitz, 2003). Solarization requires the use of clear or black plastic (or like material) to cover the soil surface for a prolonged period. Elevated temperatures below the tarped surface have also been related to seed mortality, ultimately depleting the weed seed bank (Rubin & Benjamin 1984). Generally, soil temperatures must be raised above 50°C before significant viable seed and plant structures are considered eradicated (Rubin and Benjamin 1984). We hypothesized that extensive tarping of pepperweed patches would deplete the plant's carbohydrate reserves and simultaneously decrease seed viability. While the efficacy of solarization for the control of herbaceous perennial weeds has not been widely examined, tarping has been shown to be effective used in combination with fresh cut-stump treatments of

Garlon 4 for the invasive tree *Acacia dealbata* (Horowitz, 2003; Linke 1994). Perennial species have been less affected by solarization than annual species due to their large perennial root structures which allow them to persist through extended periods of solarization (Linke 1994; Rubin & Benjamin 1984). Some annual species, but no perennial species in the Brassicaceae family, have been effectively eradicated using solarization techniques for up to 50 days (Linke 1994). Given the rigorous nature of pepperweed growth, tarping alone may reduce pepperweed density and vigor immediately following treatment, but would not provide long term control. In addition to testing the efficacy of tarping, we tested if other forms of disturbance, specifically tilling, coupled with extended periods of solarization would be sufficient to reduce perennial pepperweed infestations.

2.2. Study Sites

Figure 1. Plots tested for herbicide and non-chemical control success, experimental controls, and no treatment controls, for the perennial pepperweed control project.



2.2.1. Tihuechemne Slough (TS)

Tihuechemne Slough is a converted agriculture field and is surrounded on three sides by rice fields. It floods with fair frequency because it is positioned between rice fields and manmade channels. The most common species observed here are non-native grass *Cynodon dactylon* and weedy forbs *Lepidium latifolium*, *Picris echioides*, and *Xanthium strumarium*.

2.2.2. Silverado (SV)

Silverado is an upland grassland restoration site with plots located both in the grassland and along the edges of a pond fed by an adjacent wetland. The Cosumnes River Preserve seeded this site with native grass species such as *Leymus triticoides, Elymus glaucus* and *Nasella pulchra* in 2002.

2.2.3. Willow Slough Trail (WS)

The main visitor center trail winds through Willow Slough Trail and is both open grassland and restored Valley Oak forest. Dominant species are *Quercus lobata*, *Lolium multiflorum*, *Cynodon dactylon*, and *Distichlis spicata*.

3.0 Materials and Methods

Forty-eight plots at three properties were selected for the tarping experiment. At each site eight plots were treatment plots, while the other eight were non-treatment control plots. Four of the treatment plots at each site were mowed, rototilled, and cleared of vegetation, while the other four were mowed and cleared of vegetation. Once the two treatments were completed, 24 plots were tarped with black plastic. Each plot, 3 by 3 meters in size, was monitored for *L. latifolium* stem count and percent cover as well as the percent cover of non-target species one year prior to treatment.

In the spring, when standing water had subsided and early season species began to germinate, all plots were treated and eight 25 foot by 25 foot black plastic tarps were installed at each site. The area tarped was based on previous research which showed that roots of *L. latifolium* could travel via rhizomes up to three meters (Blank & Young 2002). The enlarged area ensured that *L. latifolium* plants within the 3m by 3m plot would not sprout stems into surrounding un-invaded vegetation. The tarps were made out of a thick black plastic landfill lining material and were reinforced at each corner and at 28 locations along the tarp edges with heavy-duty all-weather tape. Bent rebar was hammered into the ground at each corner and at the midpoint of each tarp edge. Six-inch lawn staples were hammered into the 24 remaining tape reinforced locations. Tarps remained in place for two growing seasons. Upon tarp removal, all plots were surveyed for pepperweed density as well as non-target vegetation.

3.1. Data Analysis

Data were entered into a Microsoft Access database (v. 2003) and analyzed using JMP IN 5.1 (SAS Institute, Cary, NC). All data was analyzed using ANOVA or paired t-test.

4.0 Results

4.1. Treatment Comparison

4.1.1. Mow, Disk & Tarp vs. Mow & Tarp

There was no significant difference between mow, disk, tarp (M+D+T) and mow, tarp (M+T) treatments at all sties (Figure 1; p<0.16). However, mow, disk, tarp plots offer more consistent results than mow, tarp plots. The variability of the mow, tarp plots is discouraging, but by tilling before tarping the mean success rate moves from an 18% increase in pepperweed stems (m+t) to 85% decrease in pepperweed stems in mow, disk, tarp plots (Figure 2; Appendix 7.1).

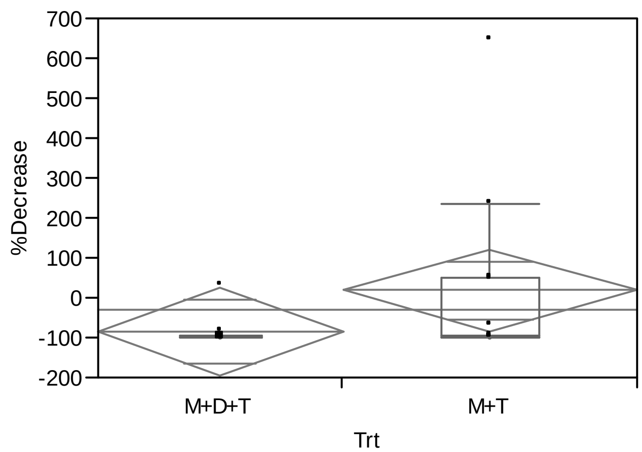


Figure 2. Percentage of pepperweed decrease in mow, disk, tarp plots and mow, tarp plots. No significant statistical difference was observed between the two treatments (p<0.16). Negative values indicate percent stem decrease from 2005 to 2005 (where a value of -100% equals complete eradication).

4.2. Site Specific

4.2.1. Silverado

Mow, disk, tarp treatments at Silverado were highly effective with a mean value of 100% success (p<0.052; Figure 3; Appendix 7.2). We had to exclude one M+D+T plot at Silverado due to tarp failure early in spring 2007. In this situation, two adjacent plots had been tarped which resulted in some overlap. One of these tarps came unsecured from its rebar anchors and while fixing this we noted pepperweed recruitment from under the damaged tarp.

Mow, tarp treatments at Silverado were 50% effective and highly variable from plot to plot (p<0.53; Figure 3). However, two of the four plots treated at Silverado were 100% eradicated of perennial pepperweed. These plots were no more or less densely populated with pepperweed prior to treatment.

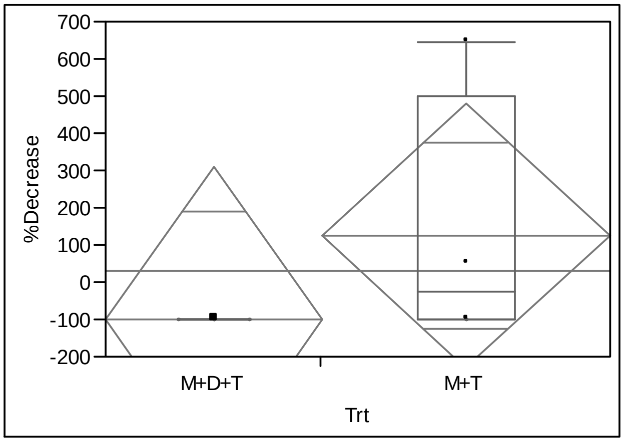


Figure 3. There was a non-significant difference in perennial pepperweed control between mow, disk, and tarp and mow and tarp treatments at Silverado (p<0.37). Negative values indicate percent stem decrease from 2005 to 2008 (where a value of -100% equals complete eradication).

4.2.2. Tihuechemne Slough

Non-chemical control at Tihuechemne Slough was highly successful in M+D+T plots and M+ T plots (mean = -94%, std = ;p<0.0001; mean = -91%, std = ; p<0.26 respectively; Figure 4). The non-significance in mow, tarp plots is related to the highly variable success rate of the treatment, which was seen in most sites at the Cosumnes River Preserve.

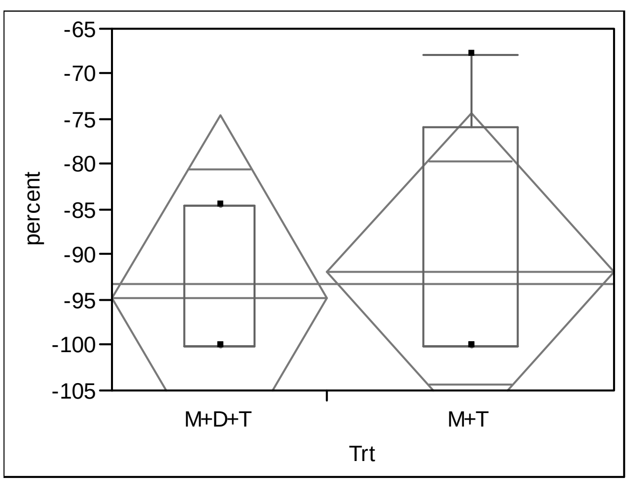


Figure 4. There was a non-significant difference in perennial pepperweed control between mow, disk, and tarp and mow and tarp treatments at Tihuechemne Slough (p<0.79). Negative values indicate percent stem decrease from 2005 to 2008 (where a value of -100% equals complete eradication).

4.2.3. Willow Slough Trail

Tarp plots that were first mowed and disked were very successful at reducing pepperweed populations by an average of 99% after two years of tarping ($p<0.08$; Figure 5; Appendix 7.2). Perennial pepperweed responded to mow, tarp treatment at the Willow Slough Trail by increasing stems by an average of 22% after two years of treatment (Appendix 7.2).

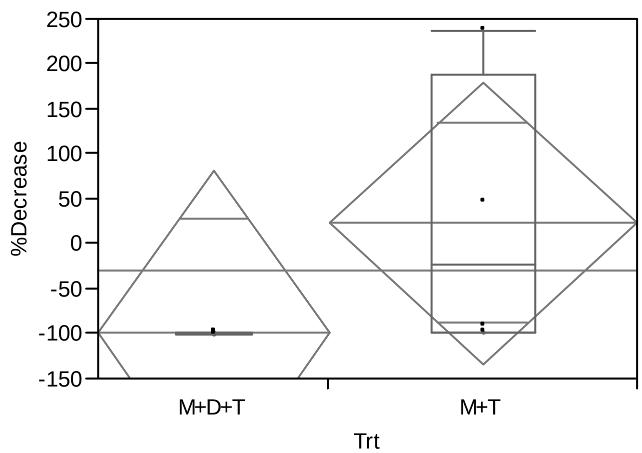


Figure 5. There was a non-significant difference in perennial pepperweed control between mow, disk, and tarp and mow and tarp treatments along the Willow Slough Trail ($p<0.24$). Negative values indicate percent stem decrease from 2005 to 2008 (where a value of -100% equals complete eradication).

5.0 Discussion

We adapted non-chemical tarping techniques by tilling the soil before tarping infested areas to further stress the perennial root structures and by lengthening the standard tarp period. By designing the experiment based on our understanding of tarping perennial plants (including *Lepidium)* and of the preserve, we were able to create a control regime that was measurably successful. This approach gave us the ability to test the effectiveness of site specific adaptations to an emerging methodology.

Mow, disk, tarp plots were more effective than tarping alone. We attribute this success to the root damage incurred by tilling the top layer of the soil. This tilling action was intended to further impair root structures by destroying the connections between the stems on the surface and their water source. We tested the hypothesis that the combined effect of heat, light exclusion, and root destruction would result in eradication.

Using mow, disk, tarp eradication would enable organic farmers to remove source populations at the Cosumnes River Preserve where herbicide application is not allowed, such as locations adjacent to rice fields or access roads. The main downfall of this type of treatment is that it is extremely labor intensive at the outset. Additionally, tarping requires monitoring and repairs throughout the period of tarp deployment and recovery.

As another means of accounting for the previous failures in controlling perennial species with tarps, we extended the standard tarping time period from one growing season to two to test if the longer time period would translate to success in mow, tarp application plots. While we extended the tarping time period, the results are too variable to recommend this type of treatment for perennial species (Benjamin 1984). The variability of success in mow, tarp plots suggest that other environmental factors may affect control success. We believe that factors like plot location, plant community, and soil type impact the efficacy of tarping.

5.1. Material selection and maintenance

General tarp failure should be monitored throughout a tarp's deployment. We found that minor repairs were necessary throughout the duration of the experiment, including fallen tree removal, hole patching, and rebar and/or stake replacement. We do not recommend overlapping tarping material. In one case, two adjacent plots were tarped but were slightly overlapping each other which caused part of one of these tarps to come loose during the winter flooding. This area was repaired early in spring, but resulted in unsuccessful pepperweed removal and exclusion from data analysis (see Section 3.2.1 for M+D+T plots at Silverado).

5.2. Implications for perennial pepperweed management in organic agriculture

While perennial pepperweed does not infest the organic rice fields at the Cosumnes River Preserve at this time, it does create issues for other crops in the region. The application of tilling and tarping pepperweed in agricultural areas would result in reduced pepperweed populations and indirectly improved agricultural outcomes (Sauerborn 1989), albeit with increased labor and material costs.

6.0 Conclusions

Based on the findings from the overall and site specific analyses we conclude that disking or tilling in combination with mowing and tarping is more effective than a mow, tarp treatment for controlling perennial pepperweed through solarization. The mow, disk, tarp method reduces the dispersal impacts of large pepperweed infestations on the surrounding habitat at the Cosumnes River Preserve. While the method does not results in 100% control every time, it is comparable to mow, herbicide techniques with Rodeo® that resulted in an average of 94% control after two years of treatment (Subtask 4.1). As with herbicide treatments, non-chemical control requires post treatment monitoring and re-treatment if eradication is the overall goal.

7.0 References

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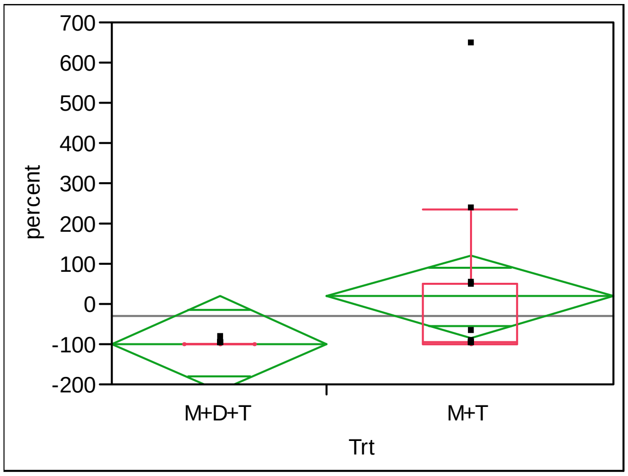
8.0 Appendix

8.1. Overall Results

Oneway Analysis of percent decrease By Treatment



Oneway Anova

Summary of Fit

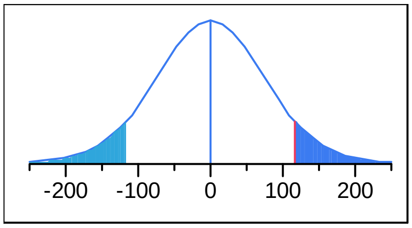
Rsquare	0.112571
Adj Rsquare	0.065864
Root Mean Square Error	169.9055
Mean of Response	-31.5805
Observations (or Sum Wgts)	21

t Test

M+T-M+D+T

Assuming equal variances

Difference	116.31	t Ratio	1.552468
Std Err Dif	74.92	DF	19
Upper CL Dif	273.12	Prob > |t|	0.1370
Lower CL Dif	-40.50	Prob > t	0.0685
Confidence	0.95	Prob < t	0.9315



Analysis of Variance

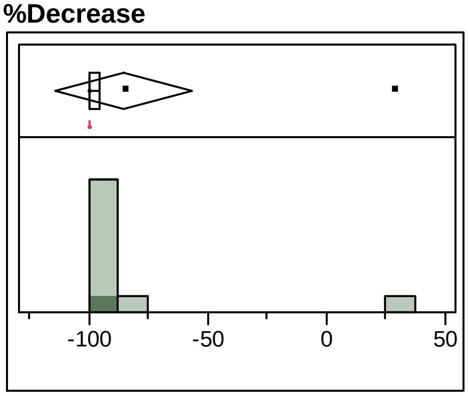
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Trt	1	69576.12	69576.1	2.4102	0.1370
Error	19	548489.91	28867.9		
C. Total	20	618066.03			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
M+D+T	9	-98.045	56.635	-216.6	20.49
M+T	12	18.268	49.048	-84.4	120.93

Std Error uses a pooled estimate of error variance

Distributions Trt=M+D+T
%Decrease



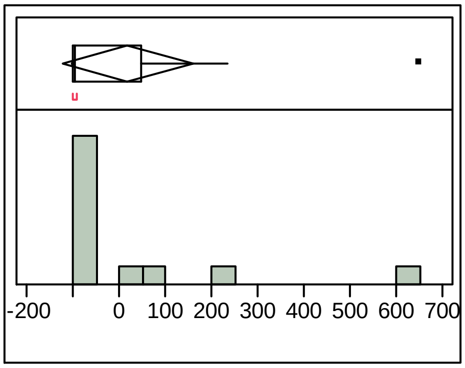
Quantiles

100.0%	maximum	29.0
99.5%		29.0
97.5%		29.0
90.0%		17.7
75.0%	quartile	-95.2
50.0%	median	-100.0
25.0%	quartile	-100.0
10.0%		-100.0
2.5%		-100.0
0.5%		-100.0
0.0%	minimum	-100.0

Moments

Mean	-85.33725
Std Dev	40.472967
Std Err Mean	12.798676
upper 95% Mean	-56.38464
lower 95% Mean	-114.2899
N	10

Distributions Trt=M+T
%Decrease



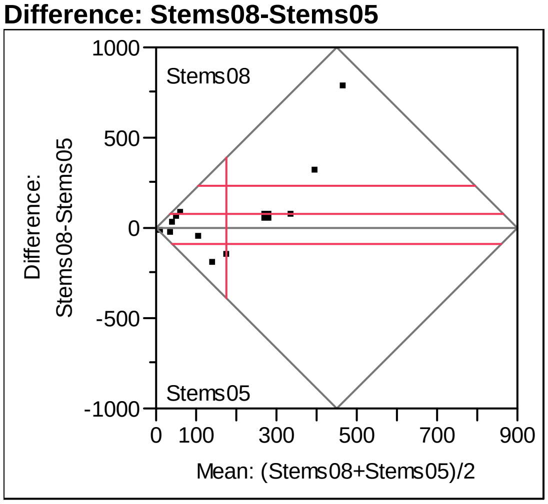
Quantiles

100.0%	maximum	647.1
99.5%		647.1
97.5%		647.1
90.0%		523.8
75.0%	quartile	49.1
50.0%	median	-96.3
25.0%	quartile	-100.0
10.0%		-100.0
2.5%		-100.0
0.5%		-100.0
0.0%	minimum	-100.0

Moments

Mean	18.267918
Std Dev	223.25711
Std Err Mean	64.448777
upper 95% Mean	160.11872
lower 95% Mean	-123.5829
N	12

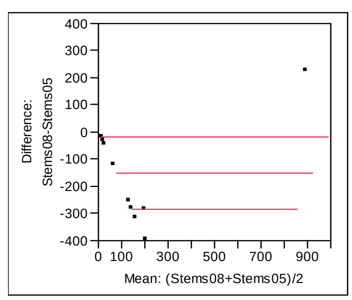
Matched Pairs Trt=LELA-CO
Difference: Stems08-Stems05



Stems08	211.167	t-Ratio	1.023199
Stems05	135.833	DF	11
Mean Difference	75.3333	Prob > |t|	0.3282
Std Error	73.6253	Prob > t	0.1641
Upper95%	237.382	Prob < t	0.8359
Lower95%	-86.715		
N	12		
Correlation	0.27187		

Matched Pairs Trt=M+D+T
Difference: Stems08-Stems05

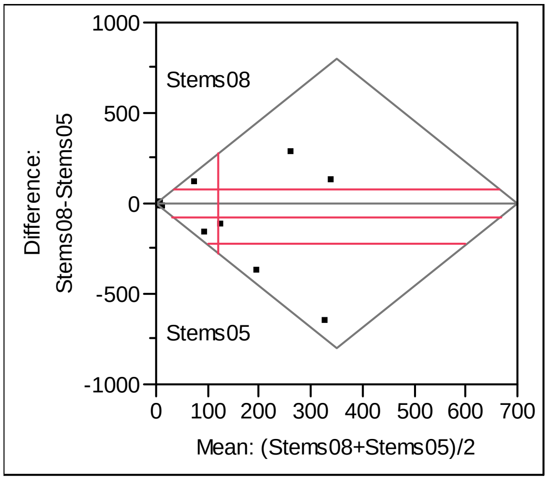
Stems08



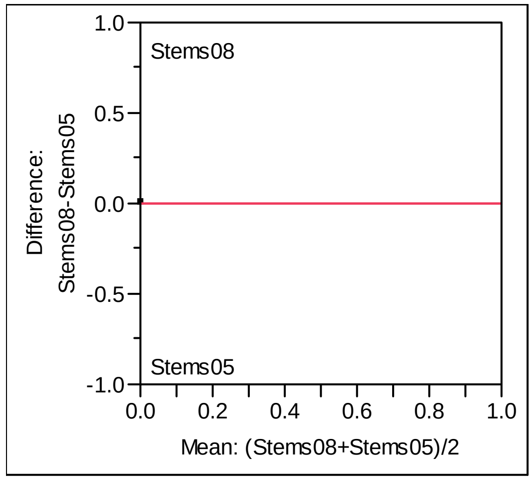
Stems05

Stems08	105.8	t-Ratio	-2.54959
Stems05	257.1	DF	9
Mean Difference	-151.3	Prob > |t|	0.0312
Std Error	59.3429	Prob > t	0.9844
Upper95%	-17.057	Prob < t	0.0156
Lower95%	-285.54		
N	10		
Correlation	0.80652		

Matched Pairs Trt=M+T
Difference: Stems08-Stems05



Matched Pairs Trt=NOLELA-CO
Difference: Stems08-Stems05



Stems08	84.1667	t-Ratio	-1.0264
Stems05	156.583	DF	11
Mean Difference	-72.417	Prob > |t|	0.3267
Std Error	70.5537	Prob > t	0.8366
Upper95%	82.871	Prob < t	0.1634
Lower95%	-227.7		
N	12		
Correlation	0.04502		

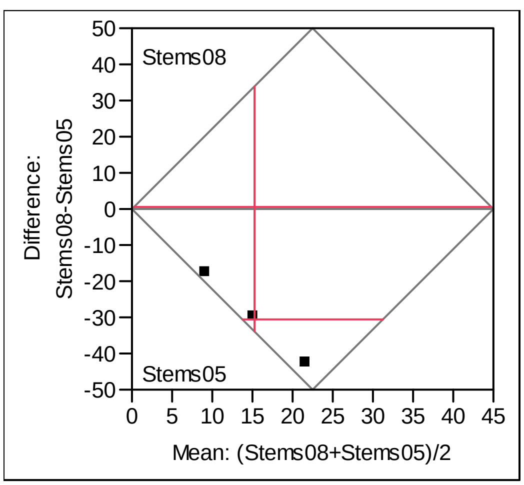
Stems08	0	t-Ratio	.
Stems05	0	DF	6
Mean Difference	0	Prob > |t|	.
Std Error	0	Prob > t	.
Upper95%	0	Prob < t	.
Lower95%	0		
N	7		
Correlation	0		

8.2. Site Specific Results

Silverado

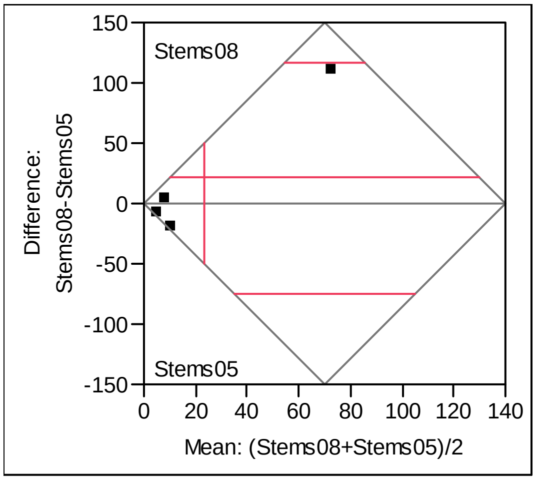
Matched Pairs Trt=M+D+T

Difference: Stems08-Stems05



Stems08	0		t-Ratio	-4.20199
Stems05	30.3333		DF	2
Mean Difference	-30.333		Prob > |t|	0.0522
Std Error	7.2188		Prob > t	0.9739
Upper95%	0.72667		Prob < t	0.0261
Lower95%	-61.393			
N	3			
Correlation	0			

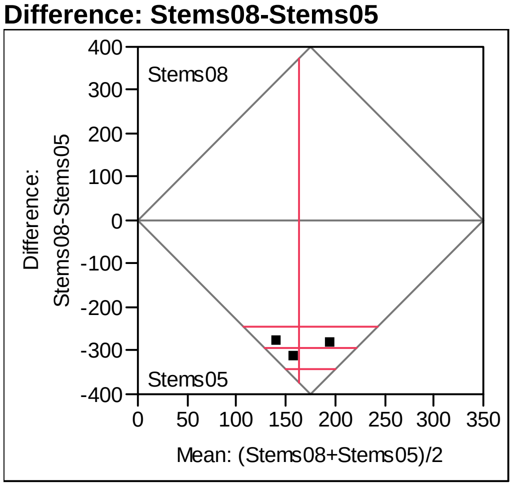
Matched Pairs Trt=M+T,
Difference: Stems08-Stems05



Stems08	34	t-Ratio	0.699159
Stems05	13	DF	3
Mean Difference	21	Prob > |t|	0.5348
Std Error	30.0361	Prob > t	0.2674
Upper95%	116.588	Prob < t	0.7326
Lower95%	-74.588		
N	4		
Correlation	0.36259		

Tihuechemne Slough

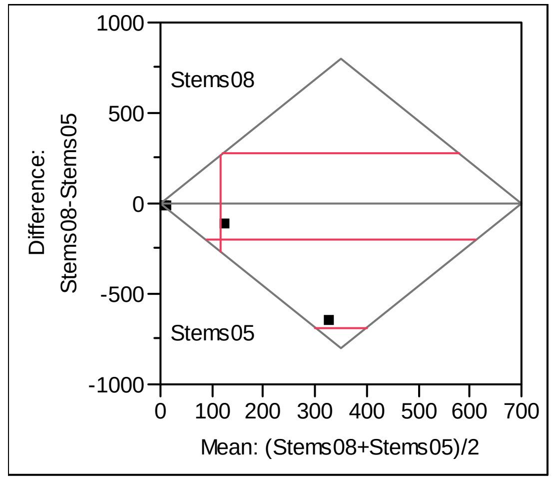
Matched Pairs Trt=M+D+T, LCEsite=T2
Difference: Stems08-Stems05



Stems08	17.3333	t-Ratio	-26.5998
Stems05	310.333	DF	2
Mean Difference	-293	Prob > |t|	0.0014
Std Error	11.0151	Prob > t	0.9993
Upper95%	-245.61	Prob < t	0.0007
Lower95%	-340.39		
N	3		

Correlation 0.78247

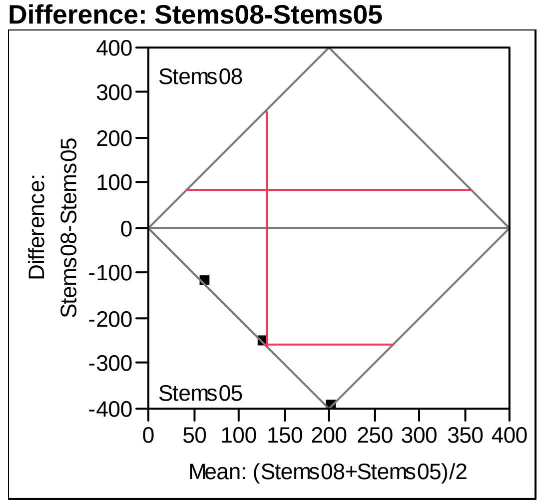
Matched Pairs Trt=M+T, LCEsite=T2
Difference: Stems08-Stems05



Stems08	15	t-Ratio	-1.35269
Stems05	219	DF	3
Mean Difference	-204	Prob > |t|	0.2691
Std Error	150.811	Prob > t	0.8655
Upper95%	275.947	Prob < t	0.1345
Lower95%	-683.95		
N	4		
Correlation	-0.0716		

Willow Slough Trail

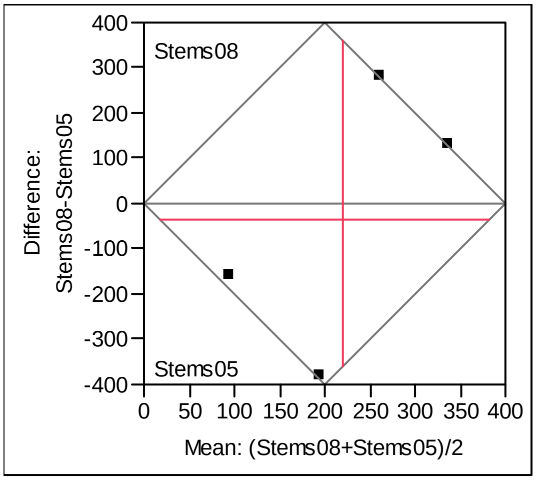
Matched Pairs Trt=M+D+T, LCEsite=T3
Difference: Stems08-Stems05



Stems08	2	t-Ratio	-3.2478
Stems05	258	DF	2
Mean Difference	-256	Prob > |t|	0.0831
Std Error	78.8226	Prob > t	0.9584
Upper95%	83.1462	Prob < t	0.0416
Lower95%	-595.15		
N	3		

Correlation	0.77602

Matched Pairs Trt=M+T, LCEsite=T3
Difference: Stems08-Stems05



Stems08	203.5	t-Ratio	-0.23121
Stems05	237.75	DF	3
Mean Difference	-34.25	Prob > |t|	0.8320
Std Error	148.136	Prob > t	0.5840
Upper95%	437.184	Prob < t	0.4160
Lower95%	-505.68		
N	4		
Correlation	-0.4251		