A test of the application of grass-specific herbicides for the enhancement of native forbs in serpentine grassland

Prepared by Don Thomas, IPM Specialist, San Francisco Public Utilities Commission

ABSTRACT

The invasion of non-native annual grasses has transformed California's grasslands, previously dominated by perennial bunchgrasses and annual forbs. These invasive grasses have replaced most of the native annual wildflowers and, to a lesser extent, the perennial bunchgrasses. California's serpentine grasslands, formerly thought to be relatively resistant to invasion by exotic invasive plants, are now also increasingly being invaded by non-native annual grasses, such as Italian ryegrass. Selective grass-specific herbicides have been suggested as a tool for the management of these invasive grasses.

This study is a test of the efficacy of three grass-specific herbicides (sethoxydim, fluazifop and clethodim) in enhancing the abundance of native annual forbs in serpentine grassland on the San Francisco Peninsula. A preliminary test performed in 2013 indicated that the application of fluazifop and clethodim may increase forb frequency, while sethoxydim may have had phytotoxic effects. A follow-up test conducted in 2014 failed to show this effect, but this result may have been due to the failure of early winter rains, which caused sparse germination of annual grasses and reduced competition with forbs. Grass-specific herbicides appear to show promise as a tool for enhancing and restoring the native forb plant community.

INTRODUCTION

Serpentine grasslands have until recently escaped invasion by exotic non-native grasses. The recent invasion by non-native grasses is due to nitrogen deposition (Weiss 2012) and the introduction of serpentine-tolerant grasses, such as barbed goat grass (Aigner and Woerly 2010).

The result of this invasion has been the displacement of native annual forbs by non-native annual grasses (Aigner, Hulvey, Koehler and Scott 2011). Efforts to restore serpentine grasslands with their original biodiversity of annual wildflowers therefore involve control of exotic annual grasses.

Use of herbicides is an effective method of selectively controlling annual grasses and of promoting native forbs and native bunchgrasses in an integrated program that includes grazing, mowing, burning and other practices. At the University of California McLaughlin Preserve application of grass-specific herbicides provided control of barbed goatgrass and increased the cover of native forbs in serpentine grassland. (Aigner and Woerly 2011) At Coyote Ridge in San Jose application of clethodim provided control of barbed goatgrass and produced an increase in native forbs (Niederer 2008). Grass-specific herbicides have also been used to restore native bunchgrassses, particularly purple needlegrass (Bell, Ekhoff and Witter 2013). Though there may be some initial phytotoxicity to purple needlegrass and other native grasses, they usually recover, and these herbicides can therefore be used to selectively control exotic annual grasses and promote native grasses.

This study was a test of the effect of the application of three different grass-specific herbicides, sethoxydim, fluazifop and clethodim, on the abundance of native forbs. These herbicides selectively control grasses while causing minimal damage to broadleaf plants. The test was performed in 2013 and repeated in 2014 in serpentine grassland in the Peninsula Watershed of the San Francisco Public Utilities Commission.

Figure 1. Serpentine grassland in the Peninsula Watershed used for upper treatment area.

Chemical	Product	Rate of Application of Product	Rate of Application of Can-Hance Surfactant	Volume Applied in 2013 to Each Test Plot	Spray Volume Applied in 2014 to Each Test Plot
Clethodim	Grassout	0.65 fl oz/gal	2 fl oz/gal	0.33 gal	0.05 gal
Fluazifop	Fusilade	0.75 fl oz/gal	2 fl oz/gal	0.33 gal	0.05 gal
Sethoxydim	Vantage	3 fl oz/gal	2 fl oz/gal	0.33 gal	0.05 gal

Figure 2. Rates of application and spray volumes used in the 2013 and 2014 grass-specific herbicide tests.

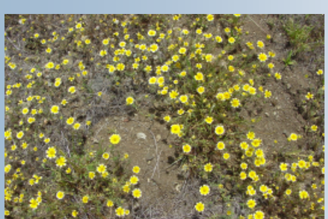

Figure 3. Appearance of serpentine grassland in the spring of 2014, showing the abundance of tidytips.

Figure 4. Treatment plots used for 2014 test of grass-specific herbicides.

	Control	Fluazifop	Clethodim	Sethoxydim
2013 Lower Area	29	54	49	8
2013 Upper Area	23	49	41	13
2014 Lower Area	35	45	42	32
2014 Upper Area	39	61	64	25

Figure 5. Summary of tidytips frequency values for upper and lower 2013 test plots measured in 2013 and in 2014.

METHODS

2013 test

Initial trials were conducted in January 2013 in serpentine grassland in the Peninsula Watershed of the San Francisco Public Utilities Commission. Blocks of 4 non-replicated 10 ft. x 10 ft. test plots were established in three different areas along a slope: lower slope with shallow rocky soil and no perennial bunchgrasses, mid-slope with deeper clay soil supporting a dense stand of *Stipa pulchra* and upper slope with shallow rocky soil and sparse native bunchgrasses. In each area each of the 4 plots received one of the following treatments: clethodim, sethoxydim, fluazifop and control. The upper treatment area is shown in Figure 1. Treatments were randomly assigned to test plots. Applications were made with small pumps sprayers. Rates of application and volumes are listed in Figure 2.

Following treatment, native forb abundance was assessed for the test plots in the lower and upper areas using a stratified random sampling method to determine forb frequency. Because tidytips (*Layia platyglossa*) was the most conspicuous and abundant native herb in the serpentine grassland (see Figure 3), frequency of tidytips was used as a proxy for total native forb abundance. Ten parallel evenly spaced transects, each with 10 randomly placed 2.7 square inch quadrats, were used to obtain frequency measurements. The native forbs of the mid-slope test area consisted almost entirely of hayfield tarweed (*Hemizonia congesta*) No frequency measurements were made for the mid-slope test plots.

A follow-up survey of the lower slope and upper slope test plots was conducted in the spring of 2014 to determine whether there were any residual effects of the 2013 treatments on the abundance of native forbs. Frequency measurements were conducted in the same manner as in 2013, using tidytips as a proxy for total forb abundance.

2014 test

In December 2013, 5 replicate blocks of 4 1 ft. x 1 ft. test plots were established on a slope near the 2013 lower slope treatment area (Figure 4). The four treatments were randomly assigned to the plots in each block. These treatments, applied on March 6, 2014, were the same as those applied in 2013 (clethodim, sethoxydim, fluazifop and control). The rates of application and application method were the same as in the 2013 test.

Because of the failure of winter rains to occur until early February 2014, the plots were manually irrigated, beginning in late December and ending in late March, to simulate normal winter precipitation and promote germination. There were a total of 18 irrigation events with a total of 14.8 inches of irrigation applied, as a supplement to the approximately 9 inches of natural precipitation that fell in the winter of 2013-2014.

On May 12 all 20 treatment plots were harvested, and all native forbs were collected. These were then air-dried for dry weight determinations.

RESULTS

2013 tests

The results of the 2013 frequency measurements for the lower and upper slope test areas are summarized in Figure 5. For the lower slope the highest frequency of forbs was found for the plot treated with fluazifop (54%), followed by the plot treated with clethodim (48%). For the upper slope area the highest frequency was also found for fluazifop (49%), followed by the plot treated with clethodim (40%). The plots treated with sethoxydim had low herb frequency, lower than that of the control plots. This suggests a possible phytotoxic effect of the herbicide. In pair-wise comparison of means in t-tests it was found that both fluazifop and clethodim plots had significantly greater frequency of forbs than the control, suggesting that they promoted forb abundance. Sethoxydim had a significantly lower frequency than the control, suggesting a phytotoxic effect on forbs.

The results of the 2014 frequency follow-up measurements for the upper and lower slopes are also presented in Figure 5. There appeared to be a residual second-year effect of the 2013 treatments. In the lower area the fluazifop treatment continued to have the highest frequency of tidytips, followed by the clethodim-treated plot. In the upper area the plot with the highest frequency of forbs was the clethodim-treated plot, followed by the fluazifop-treated plot. The sethoxydim-treated plot had lower frequency, similar to the control.

2014 test

The mean dry weight values of forbs harvested from the 2014 treatment plots are presented in Figure 6. Results were subjected to ANOVA, stratified by blocks, but there were no significant differences among treatments ($p>0.15$).

Treatment	Number of replications	Sum of dry weights	Average dry weight	Variance
Clethodim	5	40	8	2.00
Sethoxydim	5	29	5.8	2.20
Fluazifop	5	38	7.6	2.30
Control	5	35	7	2.00

Figure 6. Dry weight values of native forbs in the 2014 treatment plots.

Figure 7. Upper area treatment plot with white-rayed pentachaeta, *Pentachaeta bellidiflora*.

DISCUSSION

In this test of three grass-specific herbicides, there was a conspicuous increase in forbs, especially tidytips, in the clethodim and fluazifop-treated 2013 test plots. Other forbs included goldfields, California poppies, owl's clover, dwarf brodiaeas and checkerblooms. This increase was most evident in the lower block, which has shallow, rocky soil.

Though the treatments applied in the 2013 tests were not replicated within slope areas, there is a strong indication from the results that the clethodim and fluazifop treatments enhanced native forb abundance by suppressing competition from non-native annual grasses. These treatment plots had a higher frequency of forbs than the sethoxydim-treated and control plots in 2013, and this effect persisted in 2014.

These results agree with those of Aigner and Woerly (2011) in their work at the McLaughlin Preserve. Fluazifop and clethodim both increased native forb frequency, by 46% and 74%, respectively.

The results of the 2014 herbicide treatments, however, were inconclusive. Unlike the winter of 2013, when all of the precipitation occurred in the first half of the season, in the winter of 2014 almost no rain fell until early February. In order to make up for lack of rainfall, the test plots were manually watered with a watering can, beginning in late December 2013, and this resulted in the germination of native forbs. However, this did not simulate the natural pattern of precipitation commencing in early winter that promotes the germination and early growth of annual grasses. Once rains arrived in early February, sufficient precipitation occurred to stimulate the germination and growth of native annuals and some non-native grasses, such as *Avena* species, but the non-native grasses that germinated then lacked their early season competitive advantage. This probably explains the finding of no significant effect of the herbicide applications on dry weight of native forbs harvested from the test plots.

For the 2013 mid-slope plot, which supported a stand of native bunchgrasses, there was considerable phytotoxicity caused by all of the herbicide applications. This was still evident in 2014. Interestingly, blue fescue appeared to be less sensitive to sethoxydim than was purple needlegrass.

These results partially agree with those of Bell, Ekhoff and Witter (2013). They found that clethodim caused phytotoxicity to purple needlegrass at one site but not at another, while fluazifop caused little phytotoxicity. However, in a separate test that I performed in the Peninsula Watershed in 2014 (not reported here) I found that both clethodim and fluazifop selectively controlled *Avena* while causing only mild phytotoxicity to *Stipa pulchra*.

The serpentine grassland where the tests were performed is habitat for a federally endangered native forb, white-rayed pentachaeta (*Pentachaeta bellidiflora*). In the 2013 upper slope test area pentachaeta grew in both the clethodim and fluazifop test plots, at a frequency of about 1%, and appeared to be unharmed by these herbicides (Figure 7). These results suggest that grass-specific herbicides may be used to enhance the habitat of this endangered plant.

From the results of these tests, it appears that grass-specific herbicides may be useful for restoring and enhancing the habitat of native forbs, as part of an integrated program that includes mowing and other controls for non-native invasive grasses. However, all three of the herbicides tested have the same basic mode of action: inhibition of acetyl CoA carboxylase, an essential plant enzyme, which is involved in fatty acid synthesis. Cross resistance to both clethodim and fluzifop has developed in some grasses, including crabgrass and giant foxtail (Volenberg and Stoltenberg 2002). Therefore management of non-native grasses should not rely solely on use of these herbicides, in order to prevent the development of herbicide resistance. Sethoxydim does not appear as useful as clethodim and fluazifop for habitat restoration because of the implicated phytotoxicity to native forbs.

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