Invasive plant legacy effects and impacts on restoration strategies

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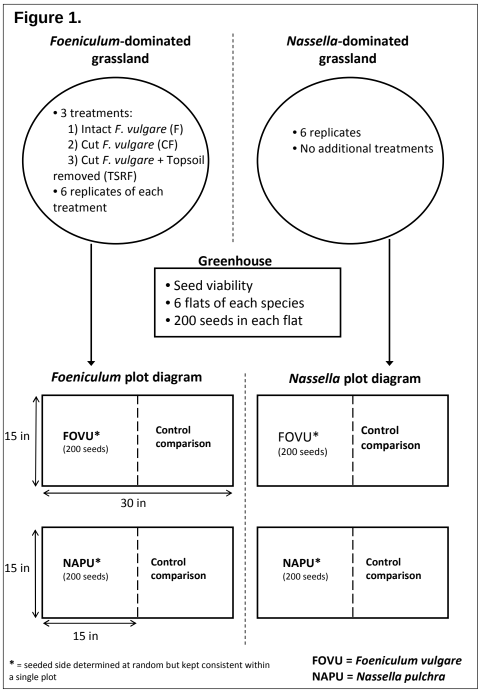
Introduction

Fennel (*Foeniculum vulgare*) is a highly successful invasive species that tends to dominate disturbed grasslands throughout California. It is suspected of altering the physical and chemical characteristics of the soil in ways that may inhibit germination or growth of native plants while having little direct effect on itself. These soil legacy effects can make restoration efforts difficult and unsuccessful. This study investigates the potential legacy effects of fennel and different restoration strategies to control them.

Previous research conducted by CCBER and the D'Antonio lab evaluated differences in soil characteristics between sections of the site that are dominated by *F. vulgare* and native perennial bunchgrass, Purple needlegrass (*Nassella pulchra*). In their lab analyses, soil conductivity (measure of salinity) under *F. vulgare* was found to be twice as high as the soil in adjacent *N. pulchra* grassland, 75 µS and 35 µS, respectively. To evaluate different restoration strategies and the importance of plant communities on soil characteristics, we conducted a reciprocal planting experiment within two habitat types—*F. vulgare*-dominated areas and *N. pulchra*-dominated areas.

Methods

Figure 1.



The experimental procedure was to plant 200 seeds each of *F. vulgare* and *N. pulchra* in 6 replicate, caged plots for 5 different treatments: (1) Intact *N. pulchra* plots, (2) Intact *F. vulgare* plots, (3) Cut and controlled *F. vulgare*, (4) Same as (3) but with 3 inches of topsoil removed. We also germinated seeds of both species in greenhouse flats to evaluate seed viability.

Soil samples were taken from all plots and analyzed for conductivity, texture, total Nitrogen, and total Carbon (organic matter). Samples of *F. vulgare* and *N. pulchra* soils were also sent to the ANR lab at UC Davis to analyze for plant-available nitrogen, phosphorous and potassium.

Results

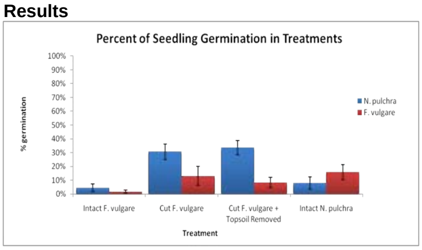
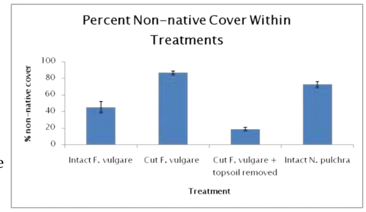


Figure 2. Germination of *N. pulchra* and *F. vulgare* in field treatments. *N. pulchra* is equally successful in cut *F. vulgare* and cut *F. vulgare* + topsoil removed. *N. pulchra* does significantly better in these treatments than in intact *F. vulgare* and intact *N. pulchra* ($p < 0.0001$). Germination of *F. vulgare* is more successful, though not significantly, within intact *N. pulchra* plots than within any of the treated fennel plots.

Figure 3. Non-native cover within each treatment. The highest amounts of non-native cover are within the cut *F. vulgare* treatment and intact *N. pulchra* treatment ($p < 0.0001$). However, most of the non-native cover was not *F. vulgare* but other non-native species such as *Vulpia myuros, Bromus diandrus, Bromus hordeaceous, Melilotus indicus* and *Vicia sativa.* Cut *F. vulgare* + topsoil removed has the lowest non-native cover ($p < 0.0001$), which is most likely a result of removing the non-native seed bank.



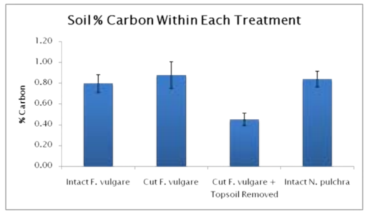
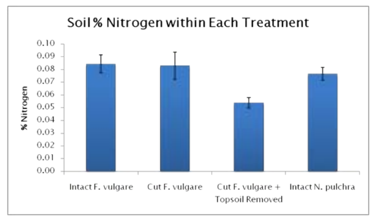


Figure 4. Soil carbon content from each treatment. Intact *F. vulgare,* intact *N. pulchra* and cut *F. vulgare* have similar levels of carbon content, while cut *F. vulgare* + topsoil removed is significantly lower than the other treatments. Removing the first 3 inches of topsoil has reduced the amount of carbon by approximately half ($p < 0.012$).

Figure 5. Soil nitrogen content from each treatment. Intact *F. vulgare,* intact *N. pulchra* and cut *F. vulgare* have similar levels of nitrogen content, while cut *F. vulgare* + topsoil removed is significantly lower that the other treatments ($p < 0.022$).



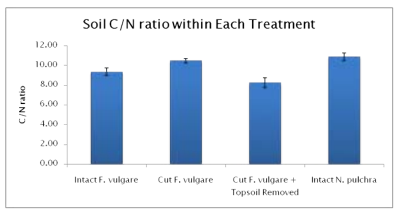


Figure 6. Soil carbon and nitrogen ratio within each treatment. Cut *F. vulgare* and intact *N. pulchra* have comparable C/N ratios. Similar to Figure 4 and Figure 5, the cut *F. vulgare* + topsoil removed treatment has a significantly lower C/N ratio than cut *F. vulgare* and intact *N. pulchra* ($p < 0.0001$), but not intact *F. vulgare*. *F. vulgare* is not significantly lower than cut *F. vulgare* or intact *N. pulchra*.

Discussion

Contrary to our hypothesis that *F. vulgare* alters soil properties and would inhibit the germination of *N. pulchra*, our results suggest that the soil in *F. vulgare* plots and *N. pulchra* plots are very similar. The elevated conductivity in *F. vulgare* plots from CCBER's initial research remained the same, but *N. pulchra* conductivity increased to similar levels as well. The carbon concentration in *F. vulgare* plots also increased from their previously low amounts in the initial research, while carbon concentrations decreased in *N. pulchra* plots. These changes in conductivity and carbon levels are most likely due to seasonal fluctuations in aerosol inputs, plant uptake or nutrient release from litter. Our data also indicates that the soil in *F. vulgare*-dominated areas does not contain legacy effects that would inhibit the germination of *N. pulchra*. Surprisingly, *N. pulchra* had the lowest germination within *N. pulchra*-dominated areas. In a study by Cory Oleson, lab analyses showed that *N.pulchra* soils had lower levels of phosphorous and potassium. The reasoning behind this may be that *N. pulchra* is more efficient in the uptake of nutrients and nutrient return from decomposing litter is slow, resulting in a habitat too low in nutrients to support the establishment of *N. pulchra* seedlings. Empty seed hulls observed within the plots suggests that consumption by insects may also be a cause of low overall germination of *N. pulchra.*

Conclusion

Ecological Understanding

• Soil characteristics (pH, conductivity, texture, total carbon, total nitrogen, and available nitrogen) are similar across all treatments except where topsoil removal resulted in lower total carbon and total nitrogen levels. This indicates that *F. vulgare* does not alter the soil to promote its own germination and/or inhibit *N. pulchra* and the low germination of *N. pulchra* in intact *F. vulgare* is likely due to shading effects rather than soil properties.

Restoration Implications

• Germination of *N. pulchra* is equally successful in cut *F. vulgare* and cut *F. vulgare* + topsoil removed; thus, topsoil removal is not required for successful germination of *N. pulchra.*
•These findings indicate that *F. vulgare* does not create legacy effects in the soil, and removal of *F. vulgare* (along with seeding of native species in this study) is a sufficient strategy to promote the growth of native plant species.

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