Can carbon addition be used to reverse the effects of atmospheric nitrogen deposition?

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Abstracts: Soil deposition of air-borne nitrogen originating from automobile exhaust has a detrimental effect on serpentine grassland because it stimulates the growth of non-native annual grasses, to the competitive disadvantage of native plants. The addition to the soil of a labile form of organic carbon, such as sucrose, has been shown to reduce plant-available nitrogen and inhibit the growth of these grasses more than that of native perennial bunchgrasses. I conducted an experiment to test the effect of carbon addition on the growth of annual grasses in test plots to which nitrogen fertilizer was applied to simulate atmospheric nitrogen deposition. The test was carried out in serpentine grassland in the Peninsula Watershed of the San Francisco Public Utilities Commission. There were four treatments: control (no sucrose and no nitrogen), addition only of sucrose, addition only of nitrogen and addition of both sucrose and nitrogen. I found that addition of carbon to unfertilized test plots significantly reduced mean dry weight (at the 0.05 level), indicating the efficacy of applying labile carbon amendments. This effect was also found for test plots that were fertilized with nitrogen. However, because there was no significant difference in dry weight between the control treatment and the treatment of only adding nitrogen, it was not possible to demonstrate that carbon addition reversed a stimulatory effect of increased nitrogen. Though these results were inconclusive, this

method should be further explored to evaluate its utility in the restoration of serpentine grassland habitat degraded by atmospheric nitrogen deposition.

Introduction

Deposition of atmospheric nitrogen from automobile exhaust and other sources poses a threat to natural ecosystems comparable to those posed by habitat loss and non-native invasive species. Nitrogen deposition results in changes in ecosystem function and loss of biodiversity. For plant communities that are naturally very low in available soil nitrogen, such as serpentine grassland, this results in an increase in nitrophilic non-native annual grasses and a loss of native forbs and perennial grasses (Weiss 1999).

In this study I tested the effect of applying organic carbon, in the form of sucrose, to the soil of serpentine grassland. Application of labile carbon has been shown to temporarily immobilize nitrogen by stimulating the growth of soil micro-organisms. Nitrogen fertilizer was also applied in this study to simulate the effect of atmospheric nitrogen deposition. The objective of the test was to determine whether carbon supplementation could be used to counter nitrogen deposition.

Methods

This study involved the application of sucrose and nitrogen fertilizer to 2 ft. x 2 ft. treatment plots set up in serpentine grassland in the Edgewood Triangle area of the Peninsula Watershed of the San Francisco Public Utilities Commission. This area is known for its serpentine flora, which includes a number of rare endemic serpentine plants. The study site was composed mostly of annual grasses, primarily *Lolium multiflorum* and *Avena* species.

Sucrose was applied at the rate of 7 oz. sucrose/4 ft^2. (480 g/m^2). Nitrogen, in the form of ammonium sulfate, was applied at the rate of 0.33 oz. fertilizer/4 ft^2. (4.5 g/m^2), equivalent to a fertilization rate of 1 lb. actual N/ 1000 ft^2. Each treatment was applied three times during the winter and spring of 2009, in February, March and April.

There were four treatments in this study: control (no sucrose and no nitrogen), addition only of sucrose, addition only of nitrogen and addition of both sucrose and nitrogen. There were 10 replicates for each treatment, giving a total of 40 treatment plots. Treatments were randomly assigned to the treatment plots.

Fertilizer and sucrose were incorporated into the soil by natural rainfall occurring just after application in February and March. In April, because expected rain failed to occur, these treatment were manually watered in.

The annual grasses were harvested in the summer of 2009, air-dried and weighed. Soil tests were performed in 2008 and 2009 by a commercial soil laboratory to determine the background level of nitrogen and other soil nutrients.

Results

The soil tests performed in 2008 and 2010 indicated that the baseline level soil nitrogen was low (8 ppm and 4 ppm respectively), as expected for serpentine soil. It was also found that the ratio of magnesium to calcium was high, as is typical for serpentine soil.

The mean values of dry weight for annual grasses were 138, 132, 56 and 69 g/m^2 for the control, nitrogen only, sucrose only and nitrogen plus sucrose treatments, respectively. The dry weight measurements for the 10 replicates of the four treatments were subjected to two-way ANOVA. It was found that sugar addition resulted in a significant reduction in dry weight compared to the control and also when compared with the treatment of only applying nitrogen ($p=0.05$). However there was no significant difference between the control and the treatment of only applying nitrogen.

Discussion

In this test the application of labile carbon significantly reduced the dry weight of non-native annual grasses. This demonstrated the efficacy of adding organic carbon to inhibit the growth of these invasive plants in restoration sites. The mechanism of this inhibition is assumed to be the immobilization of nitrogen by soil microbes metabolizing the carbon. This effect was observed for carbon addition both with and without added nitrogen.

However there was the anomalous result that the application of nitrogen did not significantly increase dry weight compared to the control. A stimulatory response to fertilizer was expected because of the low background level of nitrogen. Therefore it was not demonstrated that the application of nitrogen fertilizer simulated the effect of atmospheric nitrogen in promoting the growth of annual grasses.

The absence of this response is difficult to explain. Perhaps it was because the nitrogen was applied in three small applications rather than one large one, allowing it to be leached from the soil before it could be absorbed by the plants. Alternatively, there may have been some other limiting factor besides nitrogen affecting plant growth. In a preliminary test conducted in 2008 of applying only sucrose to the soil, there was no significant effect of carbon addition. This apparently was because it was a drought year, and soil moisture limited growth more than nitrogen availability. However, this was not the case in 2009, when there was abundant winter rainfall.

Can carbon addition be used as a tool in restoration to reverse the effects of nitrogen deposition on serpentine grassland? Although in this test it was not clearly demonstrated that added carbon can be used to counter the effects of nitrogen deposition, several researchers have found that applying supplemental carbon can be useful for meeting restoration goals in habitats with high soil nitrogen. For example, carbon amendments were found to promote native plants and reduce exotic plants in tallgrass prairie (Averett et al. 2004), along road edges of the Irvine Ranch Land Reserve in Southern California (Cleland and Suding 2007), in coastal prairies in Northern California (Alpert and Maron 2000, Krupa 2006) and in woodland tussock grasslands in Australia (Prober et al. 2005). However, carbon addition did not result in an increase in re-seeded native grass species in mixed-grass prairie in Colorado (Morghan and Seastedt 1999).

It can be concluded that carbon addition has potential offset the added nitrogen contribution from atmospheric nitrogen deposition. This has implications for the restoration of nitrogen-poor habitats, such as serpentine grassland, altered by nitrogen deposition. However additional tests are needed to demonstrate this effect.

Literature Cited

Alpert, P., and J. L. Maron. 2000 Carbon addition as a countermeasure against biological invasion by plants. Biological Invasions 2(1): 33-40.

Averett, J. M., R. A. Klips, L. E. Nave, S. D. Frey and P. S. Curtis. 2004 Effects of soil carbon amendment on nitrogen availability and plant growth in an experimental tallgrass prairie restoration. Restoration Ecology. 12(4): 568-574.

Cleland, E., and K. Suding. 2007 The role of plant trials and nitrogen availability in the success of native species restoration along roadside edges of the Irvine Ranch Land Reserve. Final Report to the Nature Conservancy and the Irvine Ranch Land Reserve.

Krupa, M.. 2006 Carbon addition in the form of sucrose and sawdust as a method of restoring native perennial grasses in two coastal California prairies.

Morghan, K.J. Reever, and T.R. Seastedt. 1999 Effects of soil nitrogen on nonnative plants in restored grasslands. Restoration Ecology. 7(1): 51-55.