BIOCHAR: AN ALTERNATIVE TO ACTIVATED CARBON IN CARBON SEEDING FOR THE ESTABLISHMENT OF PERENNIAL RYEGRASS

K.M. Trippe, K.M. Meyer, D. Watts, J.M. Novak, and M. Garcia-Jaramillo

Introduction

The ability to produce seed crops that are free of weed seed is vital to meet consumer demand, phytosanitary restrictions, and certification requirements. In the Willamette Valley, the ongoing challenge to produce weed-free grass seed is often addressed by two strategies. The first strategy delays planting until spring, when soil temperatures warm beyond a threshold that limits germination of most weedy grasses but still favors germination of the crop. However, limited moisture and vernalization can create uneven stands or delay harvest. The second strategy, carbon seeding, allows producers to establish crops in the fall by applying a narrow band of activated carbon (AC) directly over the seed furrow, followed by treatment with a broadcast preemergent herbicide (Lee, 1973; Curtis et al., 2018). The AC provides crop safety by absorbing the herbicide, essentially deactivating it within the planting row. While this method is generally effective, the combined cost of the AC and the herbicide limits its feasibility. Methods that reduce the cost—but not the efficacy—of weed control in grass seed crops are needed.

Biochar, or charcoal that is added to soil, is produced from the combustion of low-value feedstocks, including poultry litter, forest and agricultural residues, anaerobic digestate, and others. A growing interest in the use of biochar has prompted studies that evaluate its potential to condition soil, improve crop yields, and increase soil pH. The ability of biochar to bind environmental contaminants, including aromatic compounds, heavy metals, and pesticides, has also been widely examined (Khalid et al., 2020).

In general, studies have determined that the physicochemical properties of the biochar, which are determined primarily by the feedstock and production conditions, have a profound effect on biochar performance (Khalid et al., 2020). Additionally, the adsorption of pesticides depends on the chemical properties and environmental behavior of the pesticide. For example, a previous study determined that biochar produced from macadamia nut shells at high temperatures binds indaziflam and that the binding efficiency increases as the biochar ages. However, in the same study, the binding coefficient (K_d) for the herbicide terbuthylazine decreased with biochar age (Trigo et al., 2014). Because biochar:herbicide interactions vary according to the physicochemical properties of the biochar and the herbicide, it is important to evaluate these interactions on a case-by-case basis (Trigo et al., 2014; Khalid et al., 2020). In some instances, the surface area and the functional capacity of the biochar approach or exceed those of AC; as such, this study evaluated whether biochar could be a substitute for AC in carbon seeding applications.

In this report, we present the preliminary results of a greenhouse study that evaluated the level of crop safety provided by barley, juniper, and a mixed-conifer biochar toward three herbicides used in carbon banding practices: diuron, indaziflam (Alion), and a mixture of flumioxazin + pyroxasulfone (Fierce). The efficacy of these biochars to provide crop safety is compared to AC. Further studies that examine the binding capacities, mechanisms, and efficacy of these biochars under field conditions are currently underway.

Materials and Methods

Soil

The soil used in the study is a fine, silty, mixed, superactive, mesic Aquultic Argixerolls classified in the Woodburn series, which was collected from 0–20 cm at Hyslop Farm (Oregon State University, Corvallis, OR). The soil was air dried at room temperature for 10 days, sieved to 10 mm, and added to 25 cm x 25 cm x 6 cm black, high-density polyethylene plastic flats lined with landscape fabric to prevent soil loss. Soil was initially added to a depth of 4 cm. After seeding, 0.65 cm of the same soil (sieved to 5 mm) was placed on top of the seeds, for a final soil depth of 4.65 cm.

Biochar production

Barley-based biochar was produced from postharvest residue. Barley straw was collected from Hyslop Farm in the fall of 2018, baled, and transported to Florence, SC. There, the straw was mechanically reduced to pass through a 6-mm sieve. The biochar was produced by pyrolysis using a Lindburg oven with a retort at 350°C. Juniper-based biochar was produced from air-dried mill ends and kiln-dried edge strips of western juniper (*Juniperus occidentalis* Hook.), which was pyrolyzed using the flame cap method in an open-topped trapezoidal "Oregon" kiln (Wilson Biochar Associates), according to methods previously described (Phillips et al., 2020). Previous measurements estimated that maximum temperatures in the Oregon kiln reach 650–700°C (Kelpie Wilson, personal communication). Mixed-conifer biochar (Rogue Biochar) was obtained from Oregon Biochar Solutions (White City, OR). This biochar is produced at 750–950°C in a wood-fired power plant that provides energy to a local power grid. AC (Darco GroSafe) was obtained from Nutrien Ag Solutions. Biochar properties were measured as previously described (Phillips et al., 2020). Prior to application, all charcoals (biochar and AC) were dried at 70°C for 48 hours and ground using a NutriBullet grinder to < 150 µm.

Prior to the application of biochar or AC, perennial ryegrass (*Lolium perenne* L. var. 'Morningstar', 96% germination rate) was sown at a rate of 49 seeds per flat in a 7 x 7 grid pattern (3-cm spacing) and covered with 0.65 cm soil as described above. Immediately after seeding, biochars and AC were applied as a slurry (2.21 g charcoal in 35.3 mL water) with an electric spray gun (Rexbeti 700-watt high-power paint sprayer). Charcoal was evenly sprayed over the entire soil surface of the soil flat. This amount corresponds to a rate of 300 lb/acre broadcast or 25 lb/acre in-row application. Soil flats without any charcoal treatments and flats without any herbicide treatment were seeded and plants evaluated to serve as controls. Four replicate flats were included in each treatment.

Label rates of a flumioxazin + pyroxasulfone mixture (0.104 kg Fierce/ha), indaziflam (0.07 kg Alion/ha), or diuron (2.69 kg a.i./ha) were applied to the flats in a spray booth at a 187-L/ha equivalent with the following spray booth parameters: target 25 inches below nozzle tip, fan nozzle Tee Jet 8003EVS, travel rate 2.8 mph, track path 6 feet, air pressure 40 psi. After herbicide application, the flats were distributed in a randomized block design across four benches in a glass greenhouse (18–20°C). No supplemental light was provided.

The day after herbicide treatment, each flat was watered with approximately 750 mL. For the remainder of the experiment, the flats were watered twice weekly to saturation.

The experiment started (first watering) on December 18, 2020 and ran for 45 days. Plant safety was evaluated by monitoring seedling emergence (defined as the presence of a cotyledon above the soil surface) and mortality two or three times per week and on the day before harvest. Newly emerged or dead seedlings were counted and marked with a color-coded toothpick inserted into the soil about 1 cm from the sprout. At the end of the experiment, the surviving plants from each flat were cut at the soil surface, combined into a paper bag, dried for 48 hours at 50°C, and weighed.

Data were analyzed separately for each herbicide by analysis of variance. When effects were significant, means were separated at the 5% level using Tukey's honestly significant difference test. In the no-carbon, herbicide-treated data sets, few, if any plants survived the herbicide treatment. Because little to no variation was present in this data set, they were excluded from the statistical analysis.

Results and Discussion

Our study evaluated the potential for three biochars to provide plant safety when treated with three commonly used herbicides. In general, the survival and biomass data indicated that mixed-conifer biochar provided plant safety equivalent to that provided by AC, regardless of the herbicide tested (Figure 1A). Juniper-origin biochar provided significantly less plant safety in comparison to AC when the flumioxazin + pyroxasulfone mixture was applied. While this trend was also true for diuron and indaziflam, the reduced plant safety provided by the juniper-origin biochar was not different in comparison to AC. Barley-origin biochar provided substantially less plant safety in comparison to AC, regardless of the herbicide tested. Barley-origin biochar was particularly ineffective against indaziflam and the flumioxazin + pyroxasulfone mixture.

Few plants germinated or survived when no charcoal was applied to the soil surface prior to herbicide application (Figure 1B); conversely, germination and survival rates were similar across all treatments when no herbicide was applied (Figure 1A). These results indicate that the herbicide treatments were effective and that charcoal itself was not phytotoxic. At the end of the experiment, the biomass of the surviving plants was measured. Overall, the trends observed in the biomass data reflect the trends observed in the survival data (data not shown) and indicate that, in all cases, the performance of mixed-wood biochar was similar to AC, the performance of juniper-origin biochar depended on the herbicide, and barley-origin biochar provided substantially reduced plant safety.

Biochar has been widely studied for its ability to bind herbicides; however, most studies have evaluated biochar:herbicide interactions in the context of reducing the transport, environmental impact, or residual activity of herbicides. To our knowledge, this is the first study to evaluate whether biochar can act as a substitute for AC in carbon banding applications. The preliminary results of this study suggest that some, but not all, biochars are suitable replacements for AC.

Previous studies have determined that the binding efficiency of indaziflam to biochar is likely influenced by pH, specific surface area (SSA), and the presence of organic films on the surface of fresh biochar (Trigo et al., 2014). Similar trends for diuron:biochar interactions have also been described. However, the mechanism driving biochar sorption of diuron is thought to be related to organic carbon content of the biochar. The pH of the biochars is 10.4, 10.6, and 9.2 for mixed-conifer-, juniper-, and barley-origin biochar, respectively. Thus, biochar pH is not correlated to the ability to provision safety from the effects of indaziflam or flumioxazin + pyroxasulfone herbicides. However, SSA correlates well with safety for all herbicides tested. The SSA of the biochars are 6.9, 79.7, and 418.3 m^2/g for barley-, juniper-, and mixed-conifer-origin biochar, respectively. During the production process, the mixed-conifer biochar is exposed to high temperatures and steam, which may result in substantially higher SSA than is typical of other biochars. Indeed, the SSA of the mixed-conifer biochar begins to approach that of most ACs (approximately 1,000 m^2/g), which may explain their similar behavior. A more complete characterization of the physicochemical properties of the charcoals is underway and may provide insight into their activity and behavior.

There are few viable options that reduce the cost of carbon seeding practices. Biochar is substantially less expensive than AC; at the time of publication, the cost of mixed-conifer biochar was about 55% of the cost of AC (Scott Culver and Karl Strahl, personal communication), but this biochar was as effective as AC. Future studies evaluating the efficacy of biochar in carbon seeding applications in the field are ongoing. Additional analytical studies that quantify binding

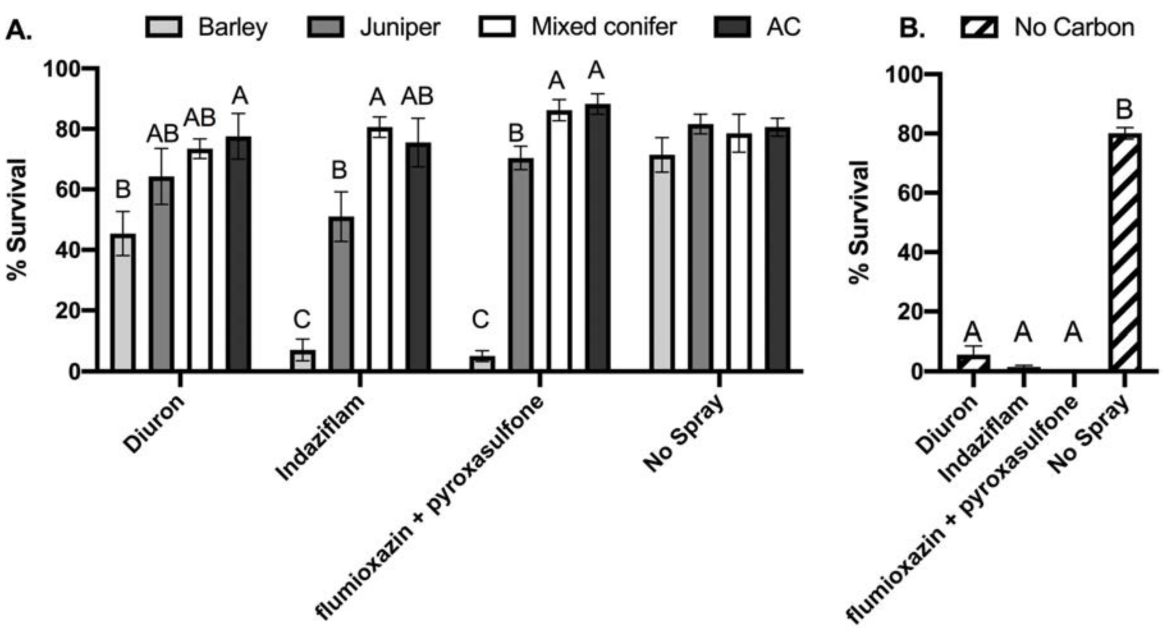

Figure 1. (A) The percent survival of perennial ryegrass (PRG) 45 days post herbicide application. Soil flats were planted with PRG and oversprayed with biochar produced from barley, juniper, or a mixed-conifer feedstock or with activated carbon (AC). Label rates of the herbicides diuron, indaziflam, and a mixture of flumioxazin + pyroxasulfone were subsequently applied. Charcoals were also applied to planted flats that did not receive an herbicidal treatment (no spray). (B) The percent survival of PRG planted without carbon (biochars or AC) 45 days post herbicide treatment. In both plots, the bars represent the mean percentage of plants surviving after 45 days (n = 4) ± standard error. Means not sharing any letter are significantly different by the Tukey HSD test at the 5% level of significance.

capacities of these herbicides to biochar are also underway. Collectively, these studies will determine which biochars are suitable for use in carbon seeding practices in the Willamette Valley.

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Acknowledgments

We thank Lori Evans for providing perennial ryegrass seeds, Pat Hayes (OSU) for providing barley straw, Andy Hulting and Caio Brunharo (OSU) for providing herbicides and assistance with herbicide application, and Oregon Biochar Solutions for providing the mixed-conifer (Rogue) biochar. This work was supported by the USDA Agricultural Research Service project in the laboratory of Kristin Trippe (2072-12620-001).