Sustaining Winter Wheat Production using Biochar Amendments in Northeast Oregon

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Introduction

Soil acidification and depletion of SOC have become widespread concerns in the dryland cropping systems of iPNW. Long-term studies of WW-SF systems in eastern Oregon show that surface 8-inch soils now have pH as low as 4.6 and have lost up to 63% and 26% of inherent SOC and total N, respectively, after more than 80 years of intensive farming. The soil pH is lowered primarily due to the application of ammonia-based fertilizer that produces acidity (H+) when converting to nitrate, the nutrient plants absorb. Nitrate-based fertilizers such as ammonium nitrate may slow acidification but are more expensive than ammonia-based fertilizers. Low soil pH (<5.5) decreases crop productivity by limiting the availability of essential plant nutrients, decreasing fertilizer use efficiency, increasing solubility of plant toxic metals such as Al and Mn, and increasing the incidence of winter kill and diseases. In addition, growing one crop in two years produces insufficient biomass to build SOC in WW-SF systems. Furthermore, intensive tillage, widely used in the WW-SF, accelerates the decomposition of residues leading to a continuous decline of SOC over time. Adopting no-till has not resulted in significant increases in SOC because of insufficient residues in WW-SF. Loss of SOC has reduced soil fertility, soil aggregate stability, and water-holding capacity, accelerated soil erosion, and threatened the sustainability of crop production within the region. In a Tillage and Fertility Long-Term WW- SF experiment established in 1940 at the Columbia Basin Agricultural Research Center (CBARC), crop yields have plateaued between 80 and 100 lb N per acre. The lack of yield response above these rates is attributable to decreasing pH (<5.0 in 120 and 160 lb N per acre treatments) and the general reduction of SOC.

Despite these problems, the WW-SF system remains popular and more reliable than annual cropping, particularly in low precipitation zones (<12 inches). In addition, soil moisture conserved during the fallow year ensures high and reliable wheat yields in the following crop year. Given that growers will continue to use the WW-SF system, there is a need to find innovative ways to build up SOC and make WW-SF sustainable. Biochar could provide the answer. Biochar is a C-rich charcoal-like product obtained by thermal decomposition (pyrolysis) of biomass or organic materials at relatively low temperatures (<700°C) in an oxygen-limited environment. Biochar can be produced from a wide variety of organic feedstock, including wood materials (tree products), non-woody materials (Kentucky bluegrass and switchgrass), and crop residues (wheat straw, corn stover, rice hulls, legume vines, bagasse, and nutshells), and animal manures (cattle, dairy, poultry, and sewage sludge). Biochar intrinsic properties depend mainly on feedstock type and pyrolysis temperature and duration.

Generally, biochars produced over 400°C are basic (alkaline) due to their increased retention of ash alkalinity that can increase soil pH of acid soils and decrease soil exchangeable Al and Mn. Furthermore, adding biochar to soil sequesters C that would have been lost to the atmosphere as CO2 through burning or natural decomposition where it would contribute to global warming. Consequently, adding biochar increases SOC. Preliminary results from our small plot studies at CBARC indicate that alkaline-biochar has the potential to increase SOC, soil pH, and yield of wheat (12 to 33%) and peas (15 to 20%) [20]. To this end, we aim to evaluate the effect of alkaline-biochar amendments on SOC, soil acidity, and crop yields under WW-SF rotation on farms in the dryland iPNW using commercial-size plots.

Tasks/Objectives

We propose to improve soil health and enhance the sustainability of WW-SF systems using biochar, charcoal produced from pyrolysis (biomass combustion at low oxygen levels)

The main objectives are:

1) To evaluate the impacts of biochar amendments on SOC, pH, active C, mineralizable C and N, bulk density, water holding capacity (WHC), electrical conductivity (EC), cation exchange capacity (CEC), base saturation, N, P, K, Ca, Mg, S, Na, Al, Fe, Mn, and Zn. Available literature indicates that biochar has the potential to improve soil's physical, chemical, or biological properties and thereby provide promising agronomic effects.

2) To investigate if soil improvements (Objective 1) due to biochar amendments increase wheat emergence, biomass accumulation, wheat N use efficiency, water use efficiency, and grain yield.

3) To determine if biochar impacts persist beyond the first year. Biochar carbon is resistant to decomposition and is known to last for hundreds of years. We want to learn whether this is true for associated soil properties and grain yield changes.

4) To communicate the research and disseminate findings through an effective education and outreach plan.

Materials and Methods

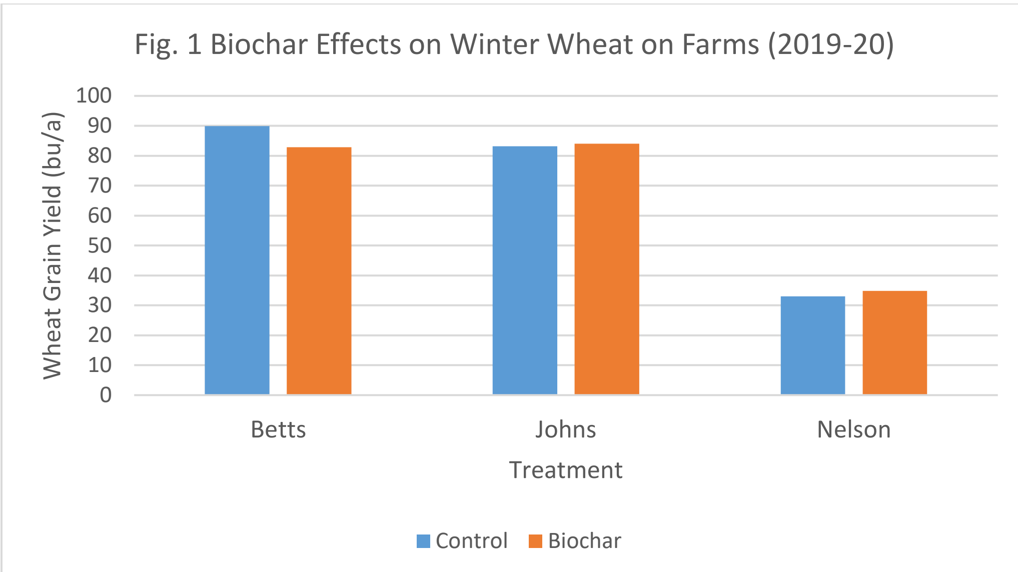
Rogue Biochar, produced by Rogue Biochar Solutions, was applied (0 vs. 2.5 tons/a) on four farms, two in a 16-18 inch precipitation zone and 2 in a 10-12 inch precipitation zone during the 2019-20 crop year. The other cooperator still has hay in the field he chose for the experiment, and biochar will be applied to his field after the removal of the hay. The biochar was produced from Douglas Fir, and its analysis shows that it had a pH of 9.48, a carbon content of 83.9%, and a liming value of 10 (see attached analyses report). No more biochar was applied on the farms, but wheat yield and soil properties data will continue to be monitored for two or more years to determine biochar effects and how long those effects persist. We obtained yield data in the 2019-20 and 2021-22 crop years. The 2020-21 crop year was a fallow year. Soil was sampled and sent for analysis after the 2021-22 wheat harvest to determine how biochar had changed soil chemical properties.

Biochar Effects on Wheat Grain Yields

Results and Discussion

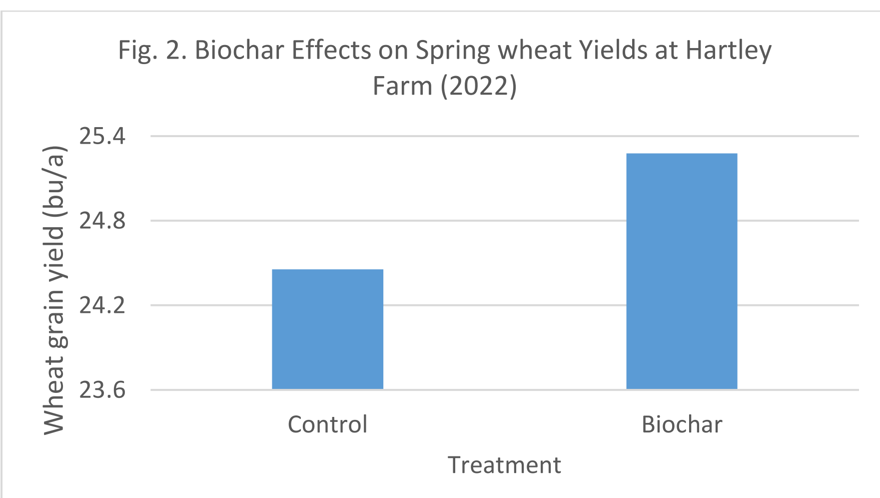
2019-20 Crop Year

Wheat yields from the 2019-20 crop year are shown in Figure 1. Farms 1 and 2 are located in the 16-18 inch precipitation zone, and farm 3 is in the 10-12 inch precipitation zone. The results show that winter wheat yield was higher in farms in the higher precipitation zones than in the farm in the lower precipitation zone. However, there were no significant differences between control (0 biochar) and biochar (2.5 ton/a) treatments at all farms, suggesting that maybe the 2.5 tons/a of biochar was insufficient to influence grain yields. In previous work, we obtained significant yield increases when biochar was applied at 5 and 10 tons/a. In this study, we decided to apply the lower rate to reduce biochar costs but based on these preliminary results, 2.5 tons/a may not be enough to increase wheat yields. We may increase the rate to 5 tons/a depending on the availability of biochar in our next experiment. We did not have any results from the Hartley because the field we were supposed to apply biochar was still in alfalfa.



2021-22 Crop Year

The 2020-21 crop year was fallow, and no yields were obtained. In the 2021-22 crop year, we planted winter wheat at the Betts, Nelson, and Johns farms and spring wheat at the Hartley farm. Figure 2 shows the effects of biochar on spring wheat at the Hartley farm. Biochar increased wheat yields, but the increase was not significantly different from the yield obtained from the control plots. Figure 3 shows the effect of biochar on winter wheat yields at the Johns and Nelsons farms. There was no significant effect of biochar on winter wheat grain yields. However, biochar decreased grain yields at the Johns farm, a high rainfall site, and slightly increased yields at the Nelson farm, the drier site. No yields were obtained from Betts farm.



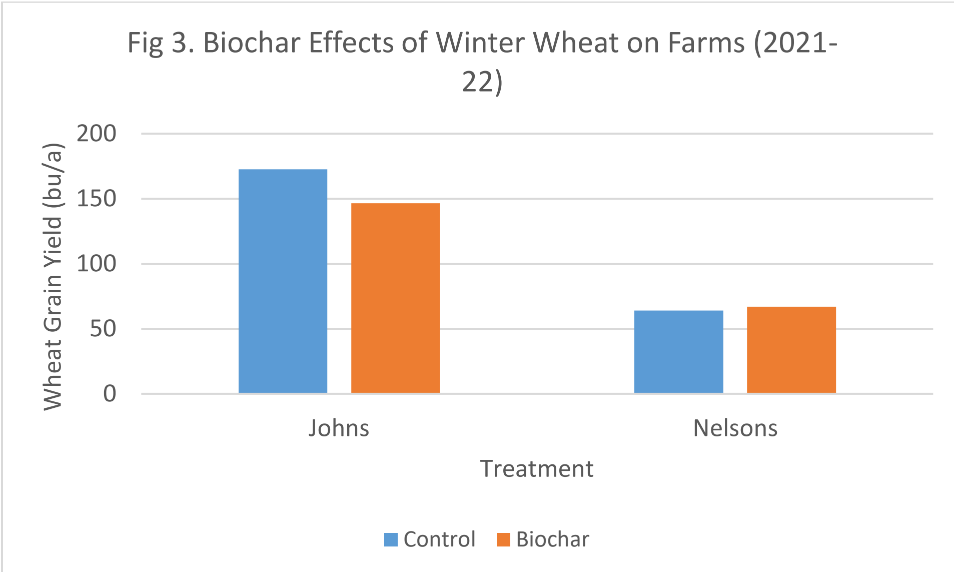
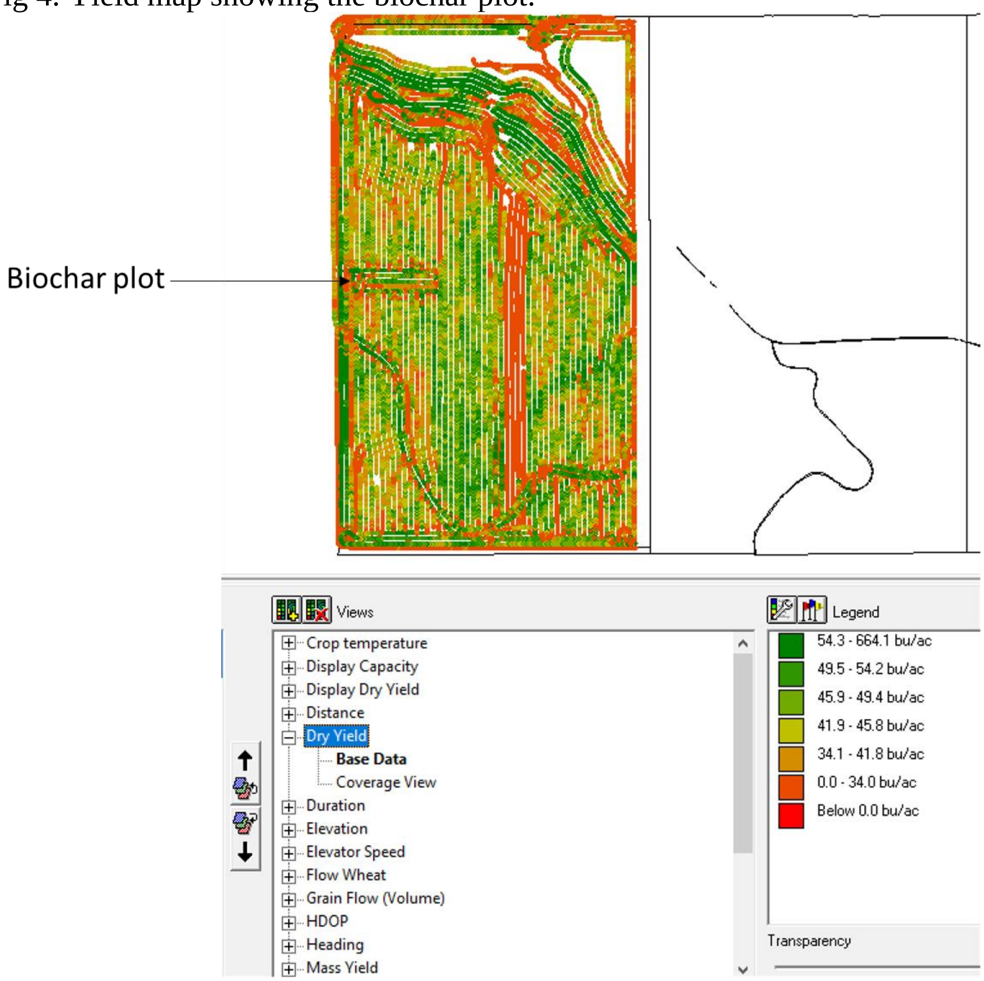


Fig 3. Biochar Effects of Winter Wheat on Farms (2021-22)

Fig 4. Yield map showing the biochar plot.



The yield map (Fig. 4) clearly shows slightly raised wheat grain yield on the biochar plot.

Biochar Effects on Soil Properties

Table 2 shows the effect of biochar on soil properties. Biochar was applied in 2019, and soil samples were analyzed in 2022. Data from all sites were analyzed together using the sites as reps. Overall, no significant differences existed between control and biochar plots on all the soil parameters measured.

Table 1. Biochar effects on soil properties.

	Control	Biochar	Units
Moisture	0.5645	0.637	%
Bulk Density	1.3315	1.3615	g/ml
EC	0.2285	0.1695	dS/m
OM	2.25	2.32	%
NH4-N	1.31	1.14	ppm
NO3-N	10.9	9.2	ppm
Bray P	31.4	33.5	ppm
Olson K	460.4	454.2	ppm
SO4-S	4.85	3.95	ppm
Cl	6.3	4.3	ppm
B	0.33	0.29	ppm
Zn	0.57	0.58	ppm
Mn	6.97	7.01	ppm
Cu	1.13	1.13	ppm
Fe	40.3	42.1	ppm
Mo	0.01	0.01	ppm
Na	0.1	0.04	meq/100g
K	1.18	1.16	meq/100g
Ca	8.9	8.4	meq/100g
Mg	3.17	2.78	meq/100g
Total Bases	13.4	12.4	men/100g
pH	6.3	5.9	-log[H+]
Al	4.35	4.15	ppm
CEC	16.6	15.9	meq/100g
Total N	0.17	0.17	%
Total C	1.14	1.14	%

Conclusions

We envisaged that applying biochar would increase some soil parameters, particularly total carbon, given that the biochar applied had about 84% C. We also expected using alkaline biochar (pH of 9.5) to increase soil pH, but no changes in soil pH were observed. The lack of response of all the measured soil parameters indicates that the 2.5 tons per acre biochar application rate was too low. As a result, the applied biochar rate did not influence grain yields. However, there was a slight increase in yield at Hartley farm in the spring of 2022 and at Nelson farm in both crop years. This slight increase is evident on the yield map. Our previous work shows that soil parameters improved and wheat and pea yield increased at 5 tons per acre biochar application rate. In trying to reduce costs, we decided to reduce the rate to 2.5 tons per acre for this experiment, but as the results show, this rate was probably too low to improve soil parameters and wheat grain yield. More experimentation with higher biochar rates is required to determine the optimum biochar rates for wheat on eastern Oregon wheat farms.