Alkaline Biochar Amendment Increased Soil pH, Carbon, and Crop Yield

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INTRODUCTION

Agricultural soils in the inland Pacific Northwest have been acidifying mainly because of the use of ammonium-based nitrogen fertilizers and have lost up to 60% of native organic C (SOC) [1]. In soils, ammoniacal fertilizers produce acidity (H^+ ion) during nitrification. Low soil pH (<5.5) limit the availability of essential plant nutrients (N, P, K, Ca, B, etc.), reduce fertilizer use efficiency, increase solubility of plant toxic metals such as Al and Mn, increase incidence of winter kill and disease, and thereby reduce crop yields [2].

Biochar is a C-rich solid produced by thermochemical conversion (pyrolysis) of biomass in restricted or absence of oxygen [3]. Alkaline biochar amendment to arable soils has been proposed as one effective countermeasure to increase soil pH, improve soil fertility and water retention, increase SOC, and enhance crop productivity [4]. However, there is limited information on the integrated effects of biochar amendments in combination with chemical N-fertilizer in cropping systems of the inland Pacific Northwest.

OBJECTIVES

- To determine the effects of biochar amendment and its rates in combination with chemical N-fertilizer on soil properties and grain yields in a 2-year winter wheat (*Triticum aestivum* L.) – spring pea (*Pisum sativum* L.).

METHODS

- Study site: An experiment was initiated in 2013 at the Columbia Basin Agricultural Research Center, near Pendleton, Oregon (45°42' N, 118°35' W).
- Soil type: Walla Walls silt loam (coarse-silty, mixed, mesic Typic Haploxeroll), 0-1% slope.
- Climate: Semi-arid temperate; 418 mm mean annual precipitation.
- Cropping history: 2 year winter wheat-summer fallow.
- Experimental design: Split-plot in 3 randomized blocks with crop phase as main-plot and biochar plus fertilizer-N treatments as sub-plot (Table 1).
- Crop rotation: 2 year winter wheat – spring pea under reduced tillage (5 cm).
  - *Wheat phase*: Semi-dwarf soft white winter wheat was planted in early October and harvested in July.
  - *Pea phase:* Spring dry-edible pea was sown in March and harvested in June.
- Biochar, derived from forest wood waste, was obtained from Biological Carbon LLC (Philomath, OR). Biochar characteristics are shown in Table 2.
- In the fall of 2013, biochar rates were surface applied and incorporated uniformly within surface 10-cm using a field cultivator. No biochar was applied thereafter.
- Urea ammonium nitrate and ammonium phosphate sulfate were shanked 10-cm deep prior to planting crops every year.
- Weeds were controlled using chemicals.
- Reference site: Grassland of native vegetation, no external inputs.
- In 2016, soils (0-10, 10-20, and 20-30 cm) were analyzed for pH, bulk density, soil organic C and total N.
- Crop grain yields were determined for the years 2014 through 2017.

Table 1. Biochar and fertilizer-N applied in the study

Treatments	Biochar rate ($Mg\ ha^{-1}$)	Fertilizer-N rate ($kg\ ha^{-1}$) Wheat	Fertilizer-N rate ($kg\ ha^{-1}$) Pea
Trt1	0	18	0
Trt2	0	94	18
Trt3	11.2	94	18
Trt4	22.4	94	18
Trt5	44.8	94	18

Table 2. Biochar characteristics

Parameters	Values
pH	10.6
Moisture content (%)	4.81
Total C (%)	90.0
Total N (%)	0.18
C:N	488
Volatile matter (%)	5.07
Ash content (%)	18.8

RESULTS

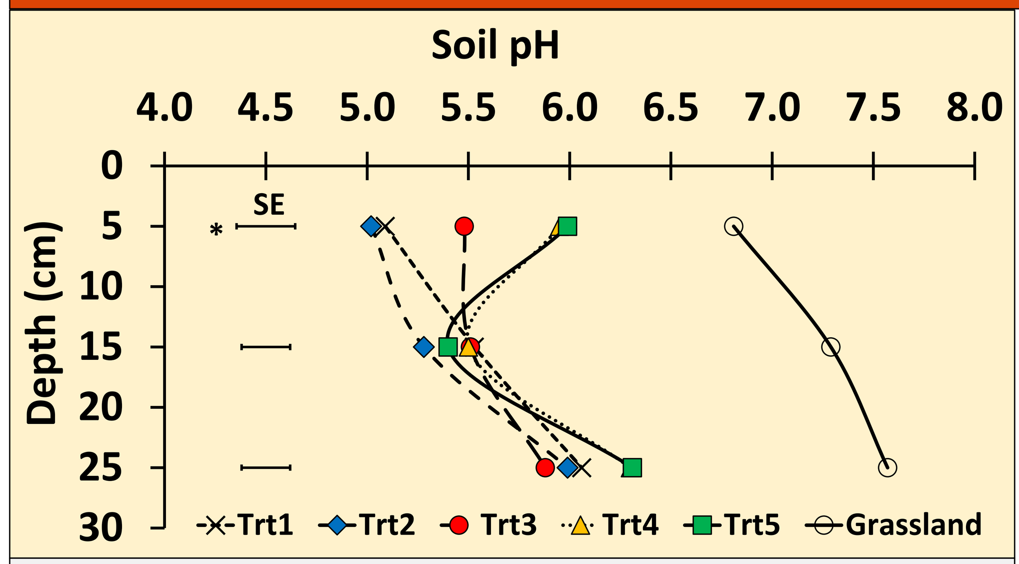

Fig. 1. Soil profile pH under treatments. Bars are standard error (SE) values of least square mean differences for depth-intervals. *Indicates significant (P<0.05) treatment differences for that depth by Tukey's HSD test. Grassland soils not included in statistical analysis.

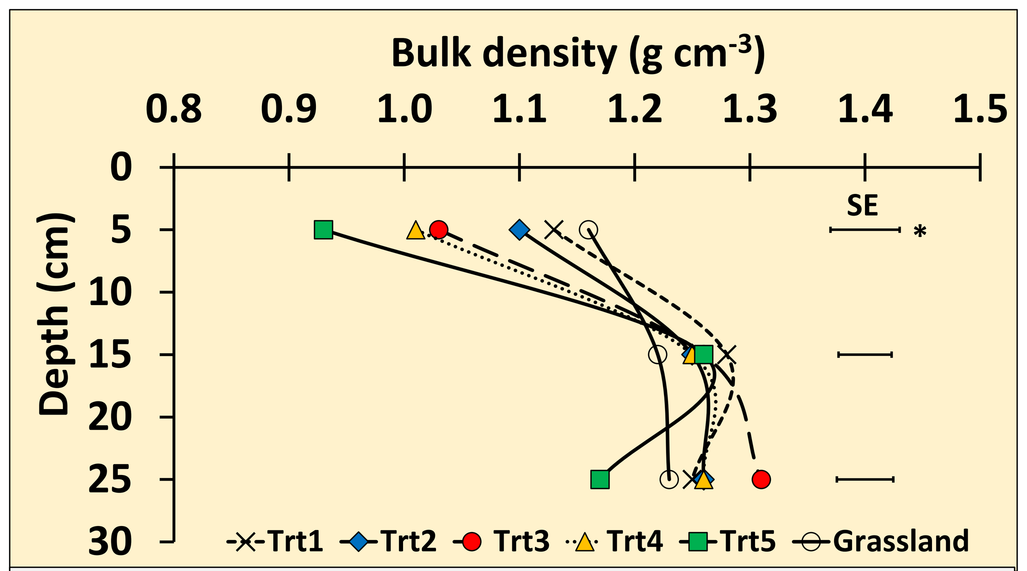

Fig. 2. Soil bulk density under treatments. Bars are standard error (SE) values of least square mean differences for depth-intervals. *Indicates significant (P<0.05) treatment differences for that depth by Tukey's HSD test. Grassland soils not included in statistical analysis.

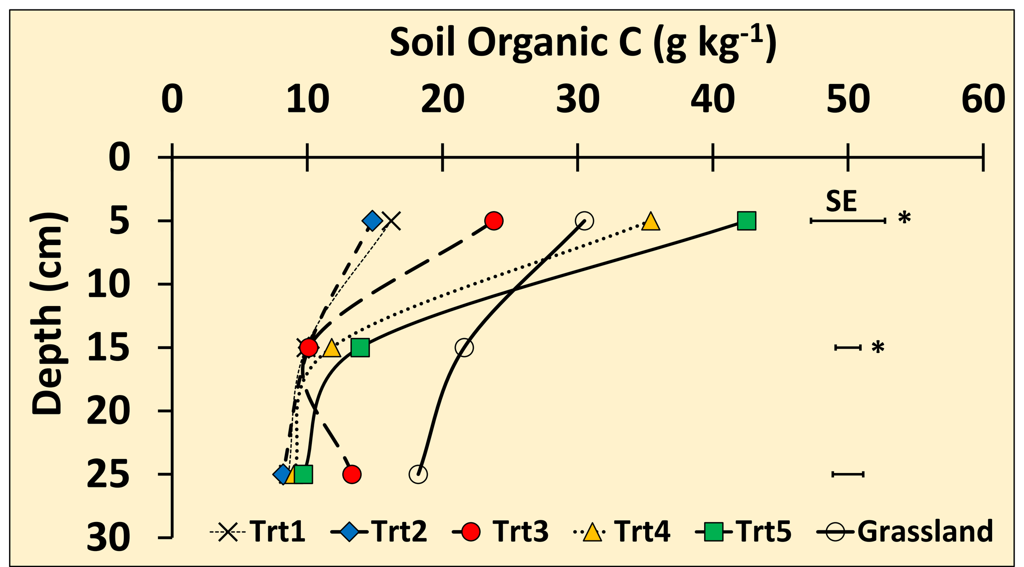

Fig. 3. Soil organic C under treatments. Bars are standard error (SE) values of least square mean differences for depth-intervals. *Indicates significant (P<0.05) treatment differences for that depth by Tukey's HSD test. Grassland soils not included in statistical analysis.

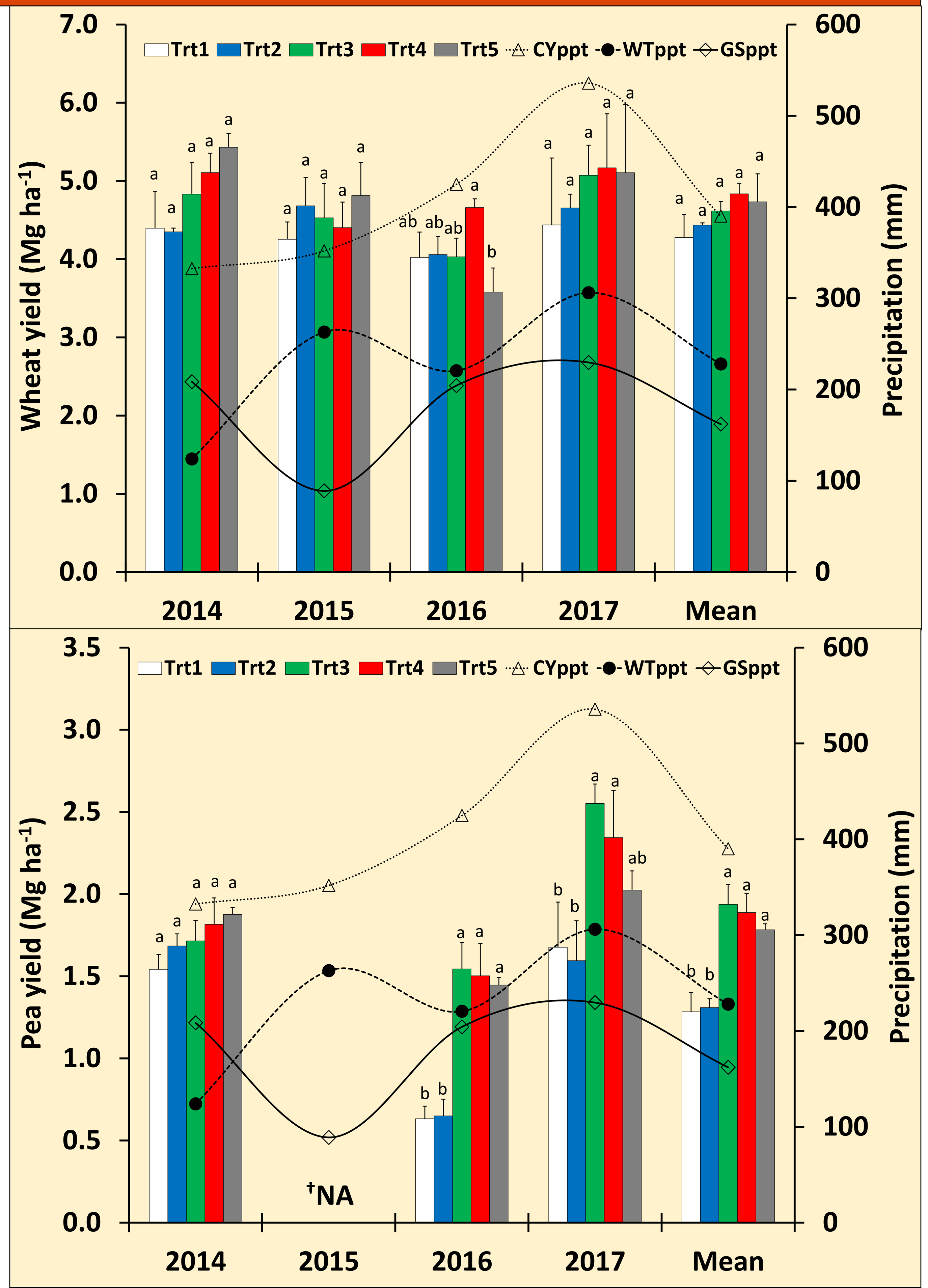

Fig. 4. Grain yields of wheat (above) and pea (below) under treatments. Means with different lowercase letters within each year are different at P<0.05 by Tukey's HSD test. Bars are standard errors of mean (n=3).CYppt, WTppt, and GSppt are crop-year (Oct-July), winter (Oct-Feb), and active growing season (Mar-July) precipitations, respectively. †NA, yield data not available for 2015.

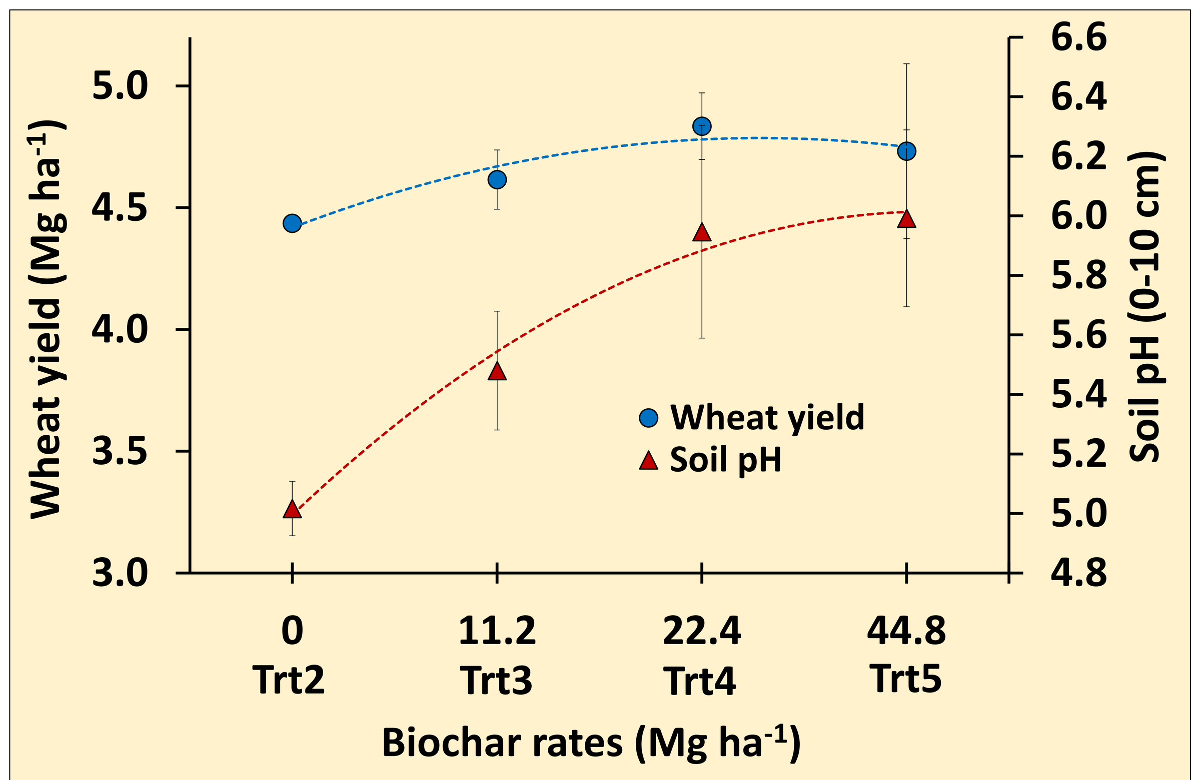

Fig. 5. Relationships among biochar rates, soil pH (0-10 cm), and wheat yields. Bars are standard errors of means (n=3).

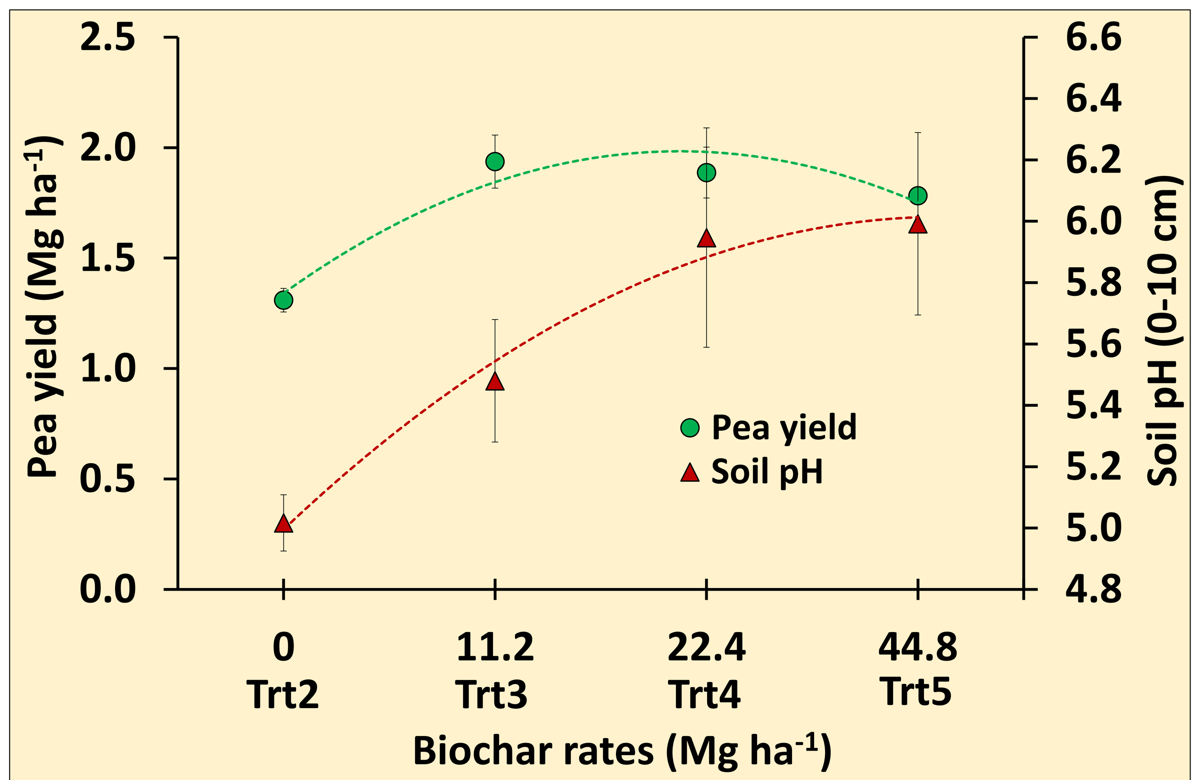

Fig. 6. Relationships among biochar rates, soil pH (0-10 cm), and wheat yields. Bars are standard errors of means (n=3).

SUMMARY AND CONCLUSIONS

- Biochar amendment increased soil pH, bulk density, and SOC at surface 10-cm compared to fertilizer-N alone application.
- Biochar amendment increased mean (2014-2017) crop yields over fertilizer-N alone application and significantly so in pea.
- Increasing biochar rates increased soil pH and SOC and decreased bulk density at surface 10-cm, but there were no responses in pea yields above 11.2 $Mg\ ha^{-1}$ biochar rate.
- Alkaline biochar has potential to increase crop yields through its positive effect on soil health in a wheat-pea rotation.
- Application of 11.2 $Mg\ ha^{-1}$ biochar rate should enhance SOC as well as prevent negative impacts of surface soil acidification on wheat-pea yields in the Pacific Northwest.

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