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# Effect of biochar on the soil nutrients about different grasslands in the Loess Plateau

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ABSTRACT

Serious soil erosion across the Loess Plateau has decreased the concentration of soil nutrients to low levels. Biochar amendments to the soil are an efficient method of improving soil nutrients; however, the effects of biochar amendments on the different soil types in the Loess Plateau are not well understood. In our experiments, we compared the effects of biochar on the soil organic matter, nitrogen and phosphorus content in the Loess Plateau. Four different grasslands abandoned in 1985, 1992, 2000 and 2005 were selected for the experiment. A 3-year field study was conducted in 2 m × 1 m plots to investigate changes in soil nutrient retention caused by biochar amendments at rates of 0 g/kg (control), 4 g/kg, 8 g/kg and 16 g/kg. The 0–40 cm soil profile was collected in layers of 0–10 cm, 10–20 cm, 20–30 cm, and 30–40 cm and the soil organic matter, total nitrogen, total phosphorus, ammonium nitrogen and nitrate nitrogen contents were measured after three years of biochar applications. The results showed that biochar amendments resulted in significant improvements to soil organic carbon, nitrate nitrogen and soil total nitrogen. When biochar was added to the 0–20 cm layer at 4 g/kg, 8 g/kg and 16 g/kg, the soil organic carbon content was increased by 2.67 g/kg, 5.34 g/kg and 10.67 g/kg, respectively; soil total nitrogen was increased by 0.24 g/kg, 0.47 g/kg and 0.83 g/kg, respectively; and soil nitrate nitrogen was increased by 0.56 mg/kg, 0.91 mg/kg and 1.63 mg/kg, respectively. Biochar amendments did not show a significant influence on soil ammonium nitrogen in the 0–20 cm soil layer. However, the soil phosphorus content decreased with increasing amounts of biochar, especially at high biochar application rates. These results show that the incorporation of biochar into the soil of the Loess Plateau has the potential to enhance the soil organic carbon and soil nitrogen contents, although it must be used in conjunction with a phosphorus fertilizer.



## 1. Introduction

The Loess Plateau covers an area of approximately $6.4 \times 10^5$ km$^2$ and is the largest continuous area of loess in the world (Wu et al., 2015). The Loess Plateau is well known for its serious soil erosion issues and long-term agricultural activity (Wang et al., 2011). Overgrazing, intensive cultivation and severe soil erosion have resulted in soil degradation (Wang et al., 2012). A number of approaches have been proposed to mitigate the degradation of the Loess Plateau and to establish a healthy ecosystem, including engineering (Xu et al., 2004) and biological approaches. The "Grain-for-Green" eco-restoration program (Deng et al., 2014), a long-term policy-driven approach established in 1999, showed that re-vegetation is the most effective method of reducing soil degradation (Zhao et al., 2015). However, trees and shrubs on the Loess Plateau have died recently, because of low nutrients and rainfall, especially in water-limited areas (Cao et al., 2010). Thus, the establishment of a healthy ecosystem requires improvements in the soil nutrient status and water content. Compost (Edmeades, 2003) and manure (Quilty and Cattle, 2011) can be used to improve the soil nutrients and water retention. However, the turnover rate of nutrients in compost and manure is rapid. Additionally, the mineralization of soil organic matter is accelerated and limits the use of organic fertilizers in the Loess Plateau (Kaur et al., 2008).

Biochar is a type of black carbon produced from animal manure or plant residues through controlled pyrolysis. The pyrolytic process converts biomass acids into a bio-oil component, and the alkalinity is inherited by the solid biochar (Laird et al., 2010). Various study results have shown that biochar application can enhance soil nutrients (Sohi et al., 2010), improve plant growth and crop yields (Major et al., 2010), and limit greenhouse gas emissions from the soil (Liu et al., 2014; Li et al., 2015). Biochar application can improve the soil water retention capacity (Peake et al., 2014; Tammeorg et al., 2014), and compared with the parent plant biomass or typical carbon forms in soil, biochar is a much more durable form of carbon (Santos et al., 2012; Knicker et al., 2013). Hence, the application of biochar to the soil has been proposed to increase the stable nutrient pool and water retention capacity. However, limited research is available on the priming effects of

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biochar on native nutrients over a long time scale. For example, biochar has been shown to increase (positive priming), decrease (negative priming) or have no effect on soil organic matter (Luo et al., 2011; Keith et al., 2011; Awad et al., 2012; Santos et al., 2012; Jones et al., 2012). Furthermore, the available research shows that the direction and magnitude of the priming effect on native soil carbon caused by biochar might change according to the incubation period. For example, studies have shown a positive priming effect in the first 2 to 3 months (Farrell et al., 2013), which decreased to either negligible or negative priming over time (Zhu et al., 2014). Biochar application can improve the soil fertility of acidic soil or rapidly lower the nutrient concentrations in tropical soils (Major et al., 2010; Vaccari et al., 2011; Zhang et al., 2012). Before applying biochar to Loess Plateau soil over a wider scope, we must first study the impacts of biochar on loess soil nutrients because these effects have not yet been demonstrated under field settings on the Loess Plateau in China.

Therefore, the aim of this work was to investigate the impacts of biochar on soil properties in the Loess Plateau. In this study, four different soil types were selected as the subjects, and the experiment was designed to meet the following two objectives: 1) study the effects of biochar application rates and 2) assess the responses of the properties of the different sol types to the biochar application. If all of the effects indicate positive priming for the soil properties, biochar will be applied as a soil amendment material on the Loess Plateau.

## 2. Materials and methods

### 2.1. Experimental site

This experiment was conducted at the Ansai research station of soil and water conservation, Chinese Academy of Science, which is located in Ansai county, Shaanxi province, NW China (36°51′6.7″–36°51′54.5″

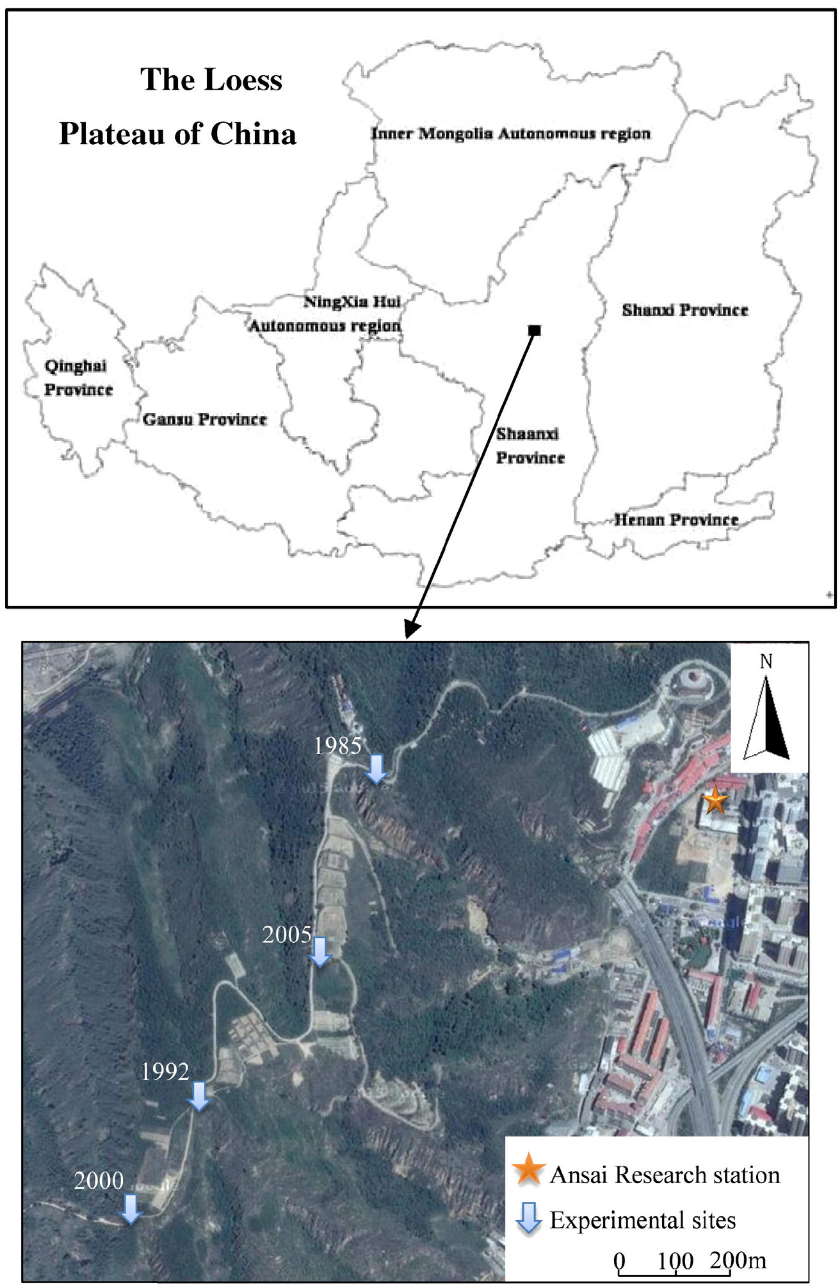


**Fig. 1.** Location of experimental sites.