Systematic analysis of biochar performance on plant growth in soybean cropping system at marginal area in Germany and China

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Abstract

Soybean (G*lycine max* L.) is the most versatile plants in agricultural system due to its high protein and oil content and the ability to associate rhizobium for biological nitrogen fixation (BNF). The cultivation of soybean is expanding on marginal area, where no soybean were cultivated. Special cultivation measure are required in those area, to facilitate the soybean cultivation especially in terms of BNF and soil fertility. This study aimed to investigate the potential effect of biochar and irrigation on soybean plant growth, crop yield formation, N budgets variation, plant nutrients uptake, and soybean-rhizobium symbiotic performance based on the analysis of soil structure, soil nutrients dynamics, and soil enzyme activities. Three field trials were conducted to accomplish our goals in Germany and China in two years. We determined the plant biomass, plant nutrient concentrations, yield components, nodule parameters, soil enzyme activities, and soil-available nutrients.

For the trail in Germany, the result showed that the biochar application caused a significant increase in the nodule number by 35% in the irrigated condition. Shoot biomass, pod number, plant height, Acid phosphomonoesterase (APM) and soil fluorescein diacetate hydrolytic activity were significantly increased by irrigation in comparison to the rainfed field. Thousand seed weight, shoot and root dry matter content were decreased by irrigation. The activity of soil protease was reduced significantly with the biochar addition in the irrigated condition. Principal component analysis, redundancy analysis and linear correlation analysis suggested that biochar application may affect soybean N uptake in the sandy field. The results interpreted the mechanism of the biochar impact on soil enzymes, BNF and crop interaction and further elucidated the potential of biochar to decrease the demand for chemical N fertilizers. Biochar application also showed the potential to enhance the relationship between nodule number and soil potassium and magnesium concentration. The APM activity was associated with the higher shoot and root phosphorus content and shoot dry weight by biochar application.

The result from the trail in China indicated that biochar increased soybean shoot biomass in loamy clay soil, but plant growth and grain yield were not enhanced by biochar in sandy fields. Three phases distribution of sandy soil showed low water holding capacity and much space between coarse sand particles. Soil type dominated the influence on soil aggregation and plant growth rather than biochar. Due to the BNF, N input in soybean cropping system was higher than in barley cropping system, and thus soybean cropping system revealed a much less N deficit. Biochar increased the soybean shoot biomass under a low soil N level in loamy clay soil, nevertheless, N balance was unaffected by biochar.

It can be concluded that biochar had a positive effect on the soybean-rhizobium symbiotic performance in the irrigated condition. Sufficient water supply is crucial on enhancing plant growth, FDA hydrolytic activity, and APM activity in sandy soil. Our results further suggested that the plant N uptake was likely more from BNF with biochar addition. Biochar may enhance soybean plant growth in loamy clay soil. Biochar unaffected the soil structure in both sandy and loamy clay soil and sandy soils showed the high soil loss potential by wind erosion. Soybean indicated more flexible and sustainable than barley on N budgets.

Keywords:

Biochar, Soybean, Biological nitrogen fixation, Nitrogen budget, Nitrogen cycling, Soil enzymatic activity, Soil structure.