Plantation of sunflowers in elevated carbon dioxide concentration by the addition of biochar: Investigation of heavy metals accumulated in plant

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Gasification is one of the popular solutions for disposing of waste biomass. One of the products of biomass gasification is biochar, a carbon-rich material. Biochar is widely used as conductive materials, adsorbents, support catalysts, etc. Specifically, one of the attractive applications is applied as an additive for planting. Numerous studies have proved the feasibility of the addition of biochar into potting substrates would enhance the aerial fresh weight (Arora et al., 2021) and reduce the accumulation of heavy metals inside the plant (Jun et al., 2020).

In recent years, in addition to the management of solid waste, global climate change caused by the increase of greenhouse gases (GHG) is also a trendy topic. Carbon dioxide is one of the significant components of GHG. The investigation of plant growth under elevated carbon dioxide concentrations also received lots of attention (De Graaff et al., 2006). Despite that, the research on plant growth under elevated carbon dioxide concentrations in the addition of biochar in potting substrates was limited.

Heavy metal accumulation in edible plants is a threat to human beings. The accumulation is highly related to the contents of their growing substrates. Several studies state the addition of biochar is safe to use for agricultural purposes. However, the nature of the growing substrates may change when it exposes to elevated carbon dioxide concentration. It may lead to the change of concentrations of heavy metals that accumulate in plants and the optimum biochar dosage for plants. Thus, it is worth investigating based on what is mentioned above.

In this work, we planted the sunflowers in elevated carbon dioxide concentration (740 ppm) and added three ratios of biochar in the potting substrates. It may make up for the current research gap in the area. To the best of our knowledge, this is the first work that studied the effect of elevated carbon dioxide and adding biochar to plants simultaneously with heavy metals analysis.

Horticultural waste from trimming landscaping plants was used as the precursor of biochar. It was gasified at 750 °C for 2 hours. The produced biochar was well mixed with compost in 15%, 30%, and 45% (weight percentage) before being further applied to the soil. The control group (0% biochar addition) was performed simultaneously. The sunflowers were planted in 740 ppm and atmospheric (415 ppm) carbon dioxide concentration. They were harvested after 14 weeks of plantation and proceeded to further characterization. The nine kinds of heavy metals were tested by inductively coupled plasma-atomic emission spectrometry (ICP-AES) in both growing substrates and sunflower plants, which are arsenic (As), selenium (Se), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), vanadium (V) and zinc (Zn).

The results show that 15% biochar application rate is the optimum ratio for obtaining the largest sunflower plant height, stem size and flower head size whether they are planted in elevated or ambient carbon dioxide concentration. Sunflowers grown in high carbon dioxide concentrations did better than those grown in the ambient environment. However, it was observed that high concentrations of carbon dioxide inhibited the positive effects of biochar on plants.

For the heavy metal analysis, it was found the heavy metals in post-harvested substrates are greater than the original substrates. The increase in heavy metals manifests the sunflower plants' take-up rate for other substances in the substrates is faster than the heavy metals. It may be because the properties of the substrates changed in high carbon dioxide (740 ppm) and leads to vital plant activity. Secondly, Ni was detected in sunflower seeds and V was detected in sunflower leaves. The surprising part is these two elements were not detected in the stem of the sunflower. It was speculated the stem only transported these two elements but didn't retain either of them. Another interesting founding is that sunflower seeds gained the most from heavy metals. It manifests that biochar maybe not be suitable to plant seed crops. Lastly, as compared the results for seed crops with Singapore food regulations (Sale of food act, chapter 283, section 56(1)) and dietary reference by Institute of Medicine in the United States (IOM), it was found the seed crops is safe to eat within certain amount (667g sunflower seeds planted in 15% biochar group/day).

This work can be instructive for future research, especially in the field of growing plants in greenhouses. The optimal biochar addition rate for sunflower growth was determined to be 15%. Also, the observed inhibitory effect of high carbon dioxide concentration on the performance of biochar addition on plants is reported for the first time. Future research could revolve around whether this inhibitory effect also occurs in other crops, and may investigate the heavy metal accumulation for green vegetable planted with the addition of biochar.

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