Graphite Nanoparticles to Enhance Growth and Reduce Nutrient Leaching in Lettuce Cultivation

IRA A. FULTON SCHOOLS OF engineering
ARIZONA STATE UNIVERSITY

Madelyn Pandorf, Paul Westerhoff
School of Sustainable Engineering and The Built Environment, Arizona State University
mpandorf@asu.edu, p.westerhoff@asu.edu

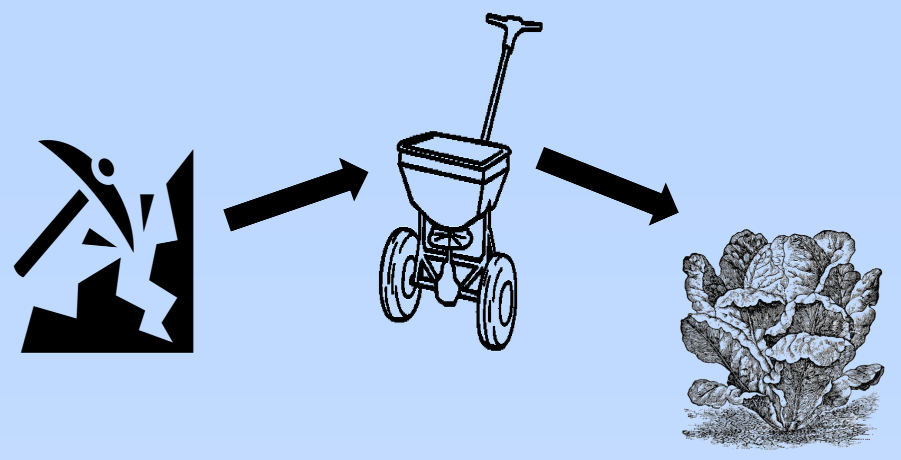
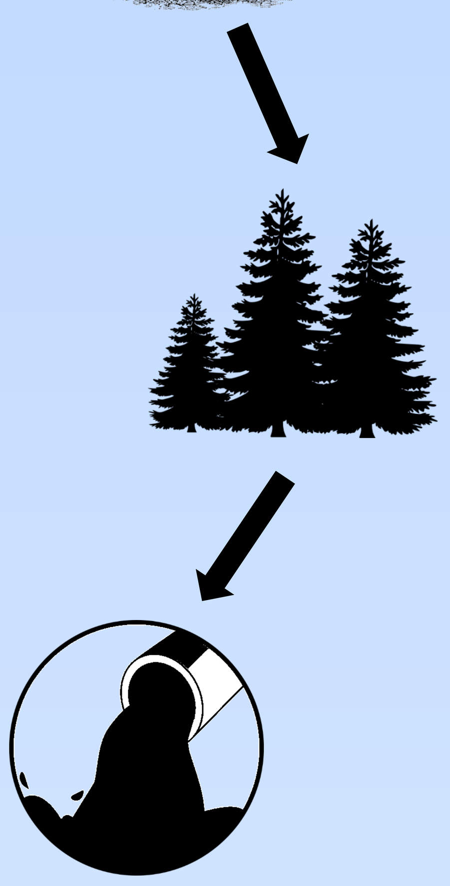

Figure 1: The current conventional method of agriculture is:

- Mine elements and produce mineral fertilizers
- Apply the fertilizer to the crops
- Crops are harvested and consumed by humans
- Excess nutrients end up leaching into the environment
- Nutrients from runoff culminate in water bodies and cause issues such as eutrophication

The Problem: Agriculture uses a large quantity of chemical fertilizers to produce crops

These fertilizers cause:

- Release of greenhouse gases
- Nutrient runoff into water bodies
- Rapid depletion of non-renewable resources such as phosphorus

The Solution: Combining fertilizers with carbon nanoparticles (CNP) can help reduce the amount of fertilizer applied therefore reducing the amount of nutrients leached into the environment

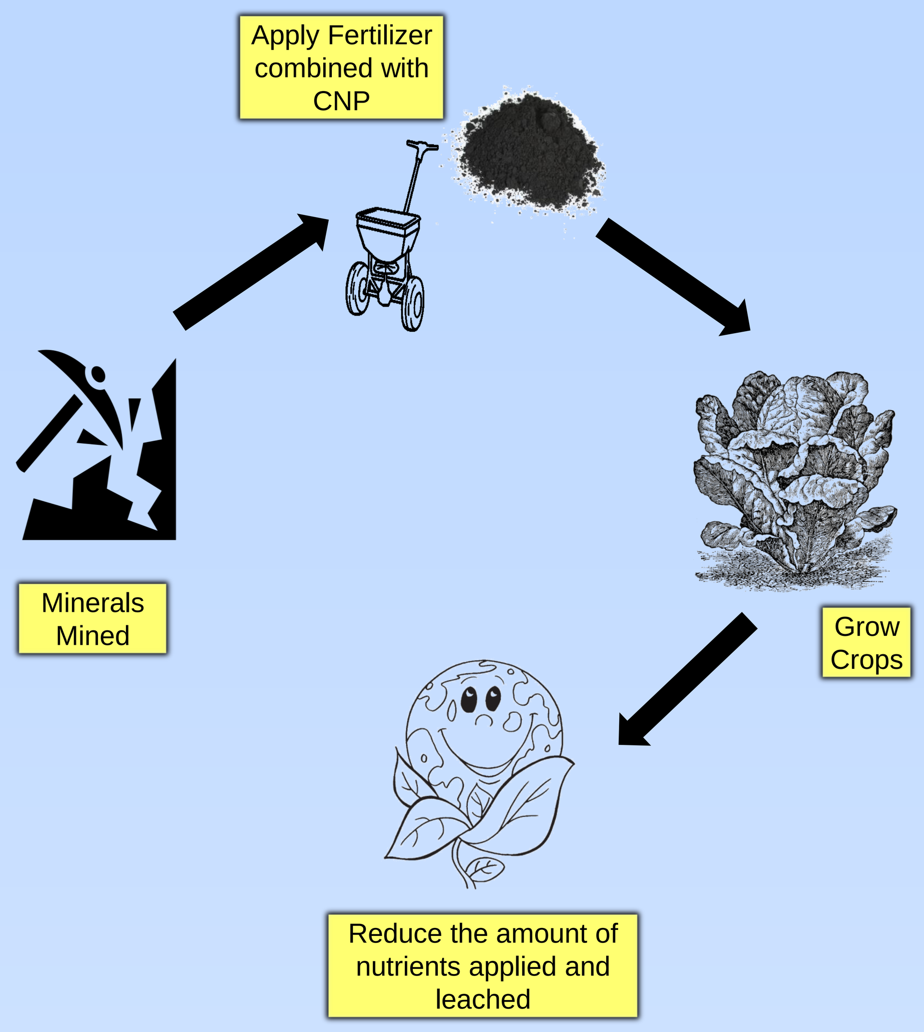

Figure 2: Combining fertilizer with carbon nanoparticles allows for 30% less of the nutrients to be applied while still producing a comparable yield. This in turn reduces the amount of fertilizer produced and the amount of nutrients such as nitrate leached into the environment.

Methods:

- Lettuce was grown in a greenhouse on ASU campus, with five different fertilizer treatments in summer and twelve in the fall.
- Carbon nanoparticles were applied at a rate of 3,000 mg/kg of fertilizer
- The treatments were: no treatment (NT), carbon nanoparticles only (CNP), 100% of recommended nutrients (NPK), 100% of recommended nutrients with the addition of carbon nanoparticles (N+C), variations of the recommended nutrient dose with and without CNP from 30-70%, biochar matching the carbon dose by weight (BM), biochar matching the % carbon of the CNP (BC), 50% of the recommended nutrients was then combined with the biochar for both mass and carbon content
- Pre-Harvest: Initial soil samples, applied first fertilizer treatment
- Growing Period: Leachate from bottom of the pots was collected bi-weekly or as needed, plants were fertilizer once midway through growing season
- Post Harvest: Wet and dry weight of vegetable, analyzed leaf, root, and soil for nutrients
- Treatments done in replicates of six in summer and four in fall

Nanomaterial Characterization:

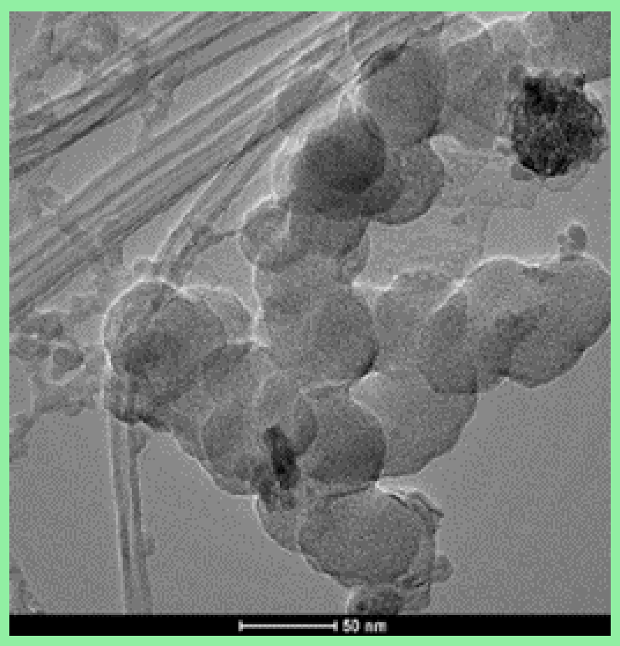
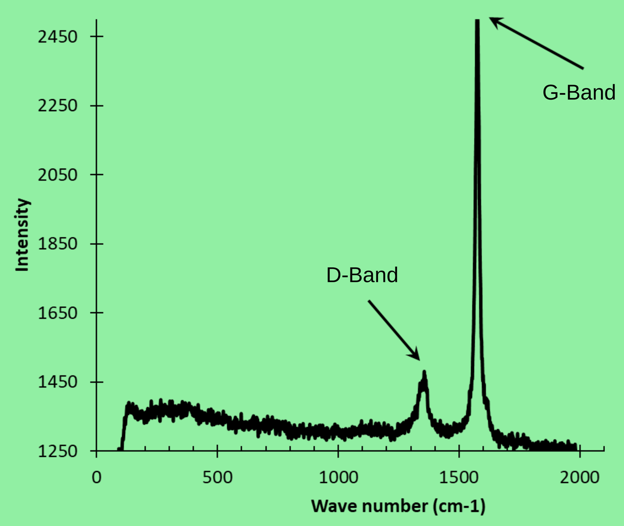

Figure 3: TEM image of the graphite nanoparticles using multiwall carbon nanotubes (hollow filaments) as a reference. Image shows particles are either spheres or are amorphous and range in size from 14-60 nm.

- Production: Electrochemical exfoliation process
- Size: 14-60 nm
- Material: 96% carbon, potassium, iron, and
- Raman: D band-1356 cm^{-1}, G band- 1574 cm^{-1}
  - Matches closely with graphite spectra
- Toxicity: Acute and chronic LD_{50} tests performed and showed no toxic effects

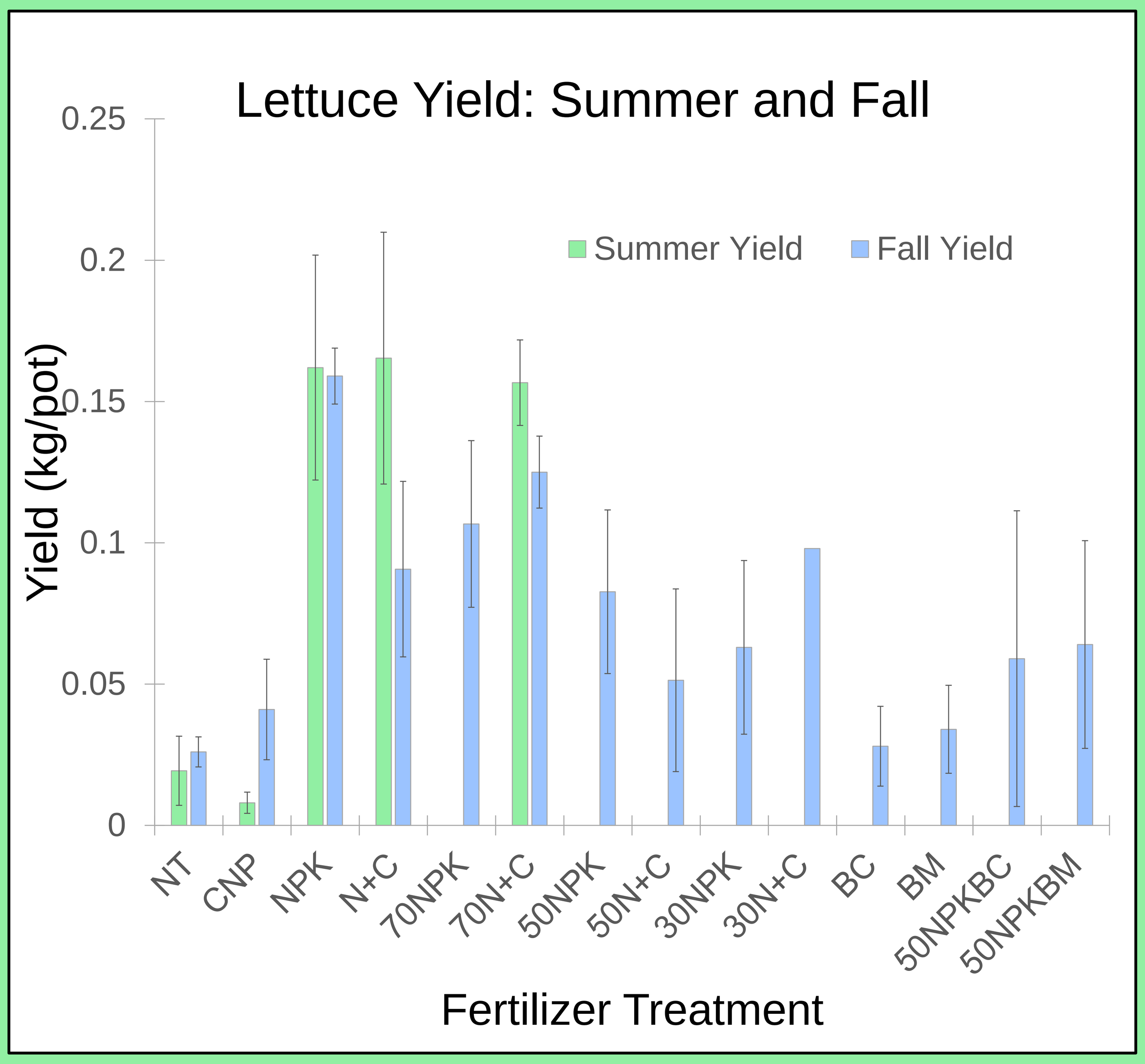

Figure 4: Yield of lettuce heads for summer and fall. Controls were no treatment (NT) and carbon nanoparticle only (CNP), then variations of the amount of nitrogen, phosphorus, and potassium ranged from 30-100% of the recommended dose both with and without the addition of carbon nanoparticles (+C indicates nanoparticle addition). Biochar was used by itself and with 50% recommended NPK. The yields show that for the 100% and 70% doses in the summer both treatments performed comparably,

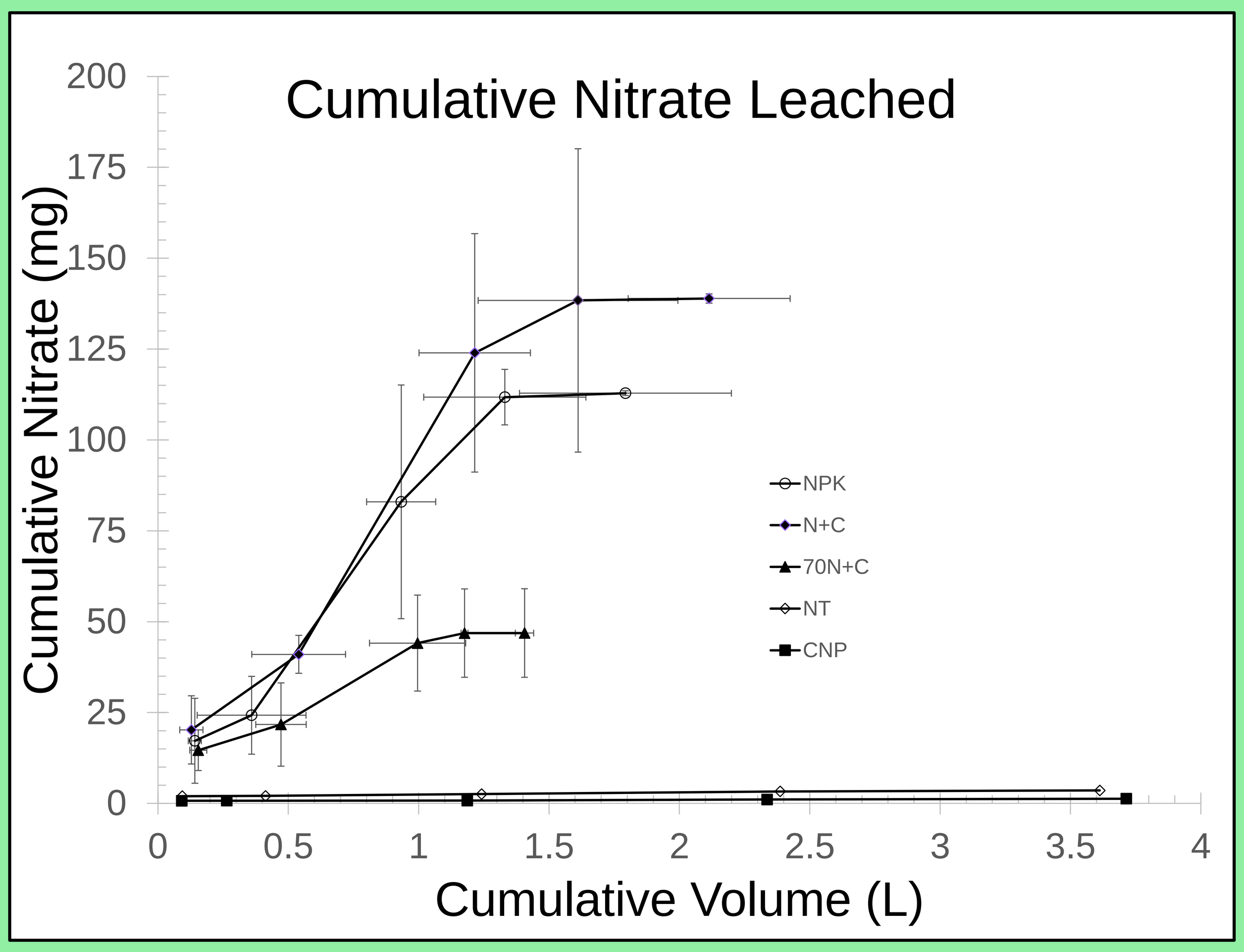

Figure 5: Shows cumulative amount of nitrate leached versus the cumulative amount of leachate collected. There is a significant reduction in the amount of nitrate leached from the 100% to 70% dose. It has been observed that the 70% dose can produce comparable yields to the 100% dose which gives the opportunity to use less fertilizer and reduce leaching while still producing the same amount of lettuce.

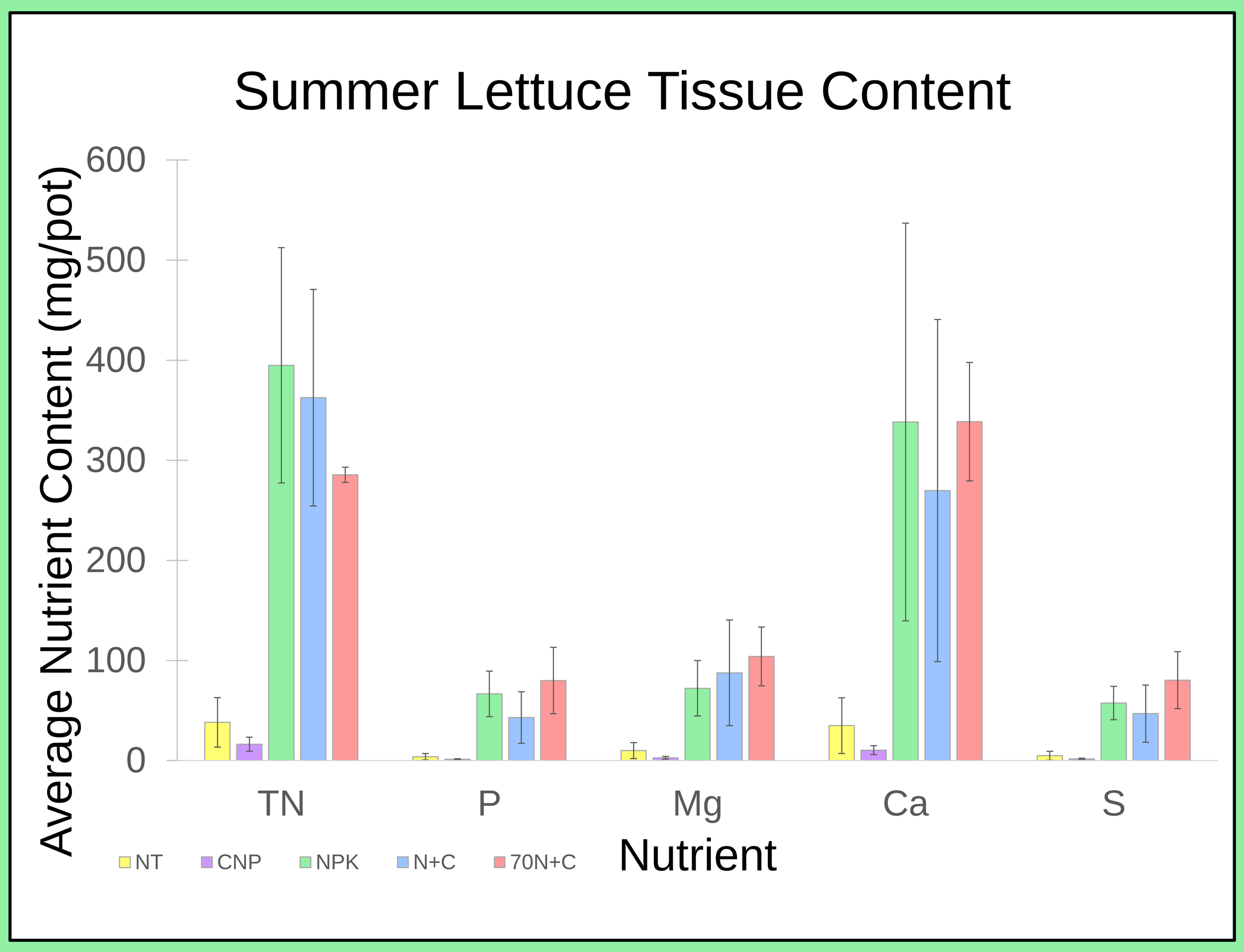

Figure 6: Compares the nitrogen (TN), phosphorus (P), magnesium (Mg), calcium (Ca), and sulfur (S) contents in the leaf and roots of the five different fertilizer treatments. The controls had the lowest nutrient content with the 100% and 70% doses having similar nutrient compositions except for nitrogen.

Future Work:

- Changing the soil types to see if that will effect the interaction and benefit of the carbon nanoparticles with the lettuce
- Varying the dose of carbon nanoparticles to see if that will reduce nutrient leachate and enhance nutrient uptake
- Comparing the leaching and nutrient uptake of bamboo biochar with the carbon nanoparticles
- Analyzing yield, nutrient leaching, nutrients in soil, nutrients in tissue for the various fertilizer treatments

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