Effects of Kaolin Clay as Ground Cover on Nutrient Composition in Apple Trees

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Abstract:

Farmers don't have a sustainable way of managing weeds. They're interested in reducing the use of chemical herbicides because of environmental concerns. One potential solution is using clay to cover the ground, effectively smothering the weeds. However, this solution may also have unintended negative consequences.

1.0 Introduction:

Mitigating weeds has long been a challenge for the agricultural industry. When plants were first selectively bred for more desirable crops thousands of years ago, unwanted vegetation always followed (Vats, 2015). Until the mid 1900's, the only viable method of weed removal was hand weeding and plowing, which are both labor intensive and time consuming (Timmons, 1970). Chemical herbicides then became common following World War II and were effective at removing weeds with little labor input (Chauvel et al., 2012). Shortly after their widespread use, weeds began building resistance to these industrial chemicals, calling for more potent and dangerous herbicides to be produced (Vats, 2015). The use of herbicides has also created negative secondary effects that damage ecosystems; contaminate soil, air, and bodies of water, as well as having unintended adverse effects on wildlife communities and people (Shepard et al., 2004). While the continued use of herbicides contributes to unsustainability in our food production systems, weeds need to be dealt with in order to produce healthy crops.

Farmers and researchers have developed means to reduce the need for herbicides, such as physical barriers that prevent weed growth, also called groundcover. One of such barriers is made up of kaolin clay, which covers the top layer of soil, in turn blocking sunlight and preventing weeds from sprouting through the clay. Past studies on the effect of kaolin clay for weed management have revealed effective control in bell pepper and blackberry plants (Keay et al., 2018, Takeda et al., 2005). However, to our knowledge, the impact of kaolin clay on soil health and nutrients has been ignored. This is concerning considering the physical characteristics of clay and their probable impact on available soil nutrients. Clays with a built-in negative charge have a unique property called cation exchange capacity (CEC) and will attract cations present in the soil like calcium, magnesium, sodium, and potassium (Marchuk et al., 2012), which can then become trapped in the clay due to their structure (Carter et al., 1986). We ignore if plants surrounded by kaolin clay are still able to access a sufficient amount of nutrients to remain healthy, or if the clay hinders their ability to grow by reducing nutrient mobility in the ground substrate.

To determine if clay has any adverse effects on nutrient availability on apple trees we examined the nutrient content of soil under different groundcover treatments. Tree foliage was also analyzed to determine if trees were able to access cations in the soil despite the addition of kaolin clay. We hypothesize that the presence of kaolin clay groundcover leads to lower nutrient concentrations in soil and leaves of orchard apple trees.

2.0 Materials and Methods

2.1 Study Site

Our study was conducted in a cider apple tree block at the University of Massachusetts Amherst Cold Spring Orchard Research Farm. Specifically, our study site was comprised of five rows of trees (Fig. 1). There are two different cultivars, or types of apple trees, we focused our study on with 40 trees per cultivar in a given row. Within one replicant of 40 trees, cultivars were divided into three treatments: treatment one trees were applied a pre-emergent herbicide spray (Chateau EZ) on March 28th, 2023; trees in treatment two were applied with a kaolin clay and mulch mixture around the base of the root stem; while treatment three trees were applied with mulch alone. Each treatment consisted of 10 trees with buffer trees in between to prevent spillover effects (Fig. 2).

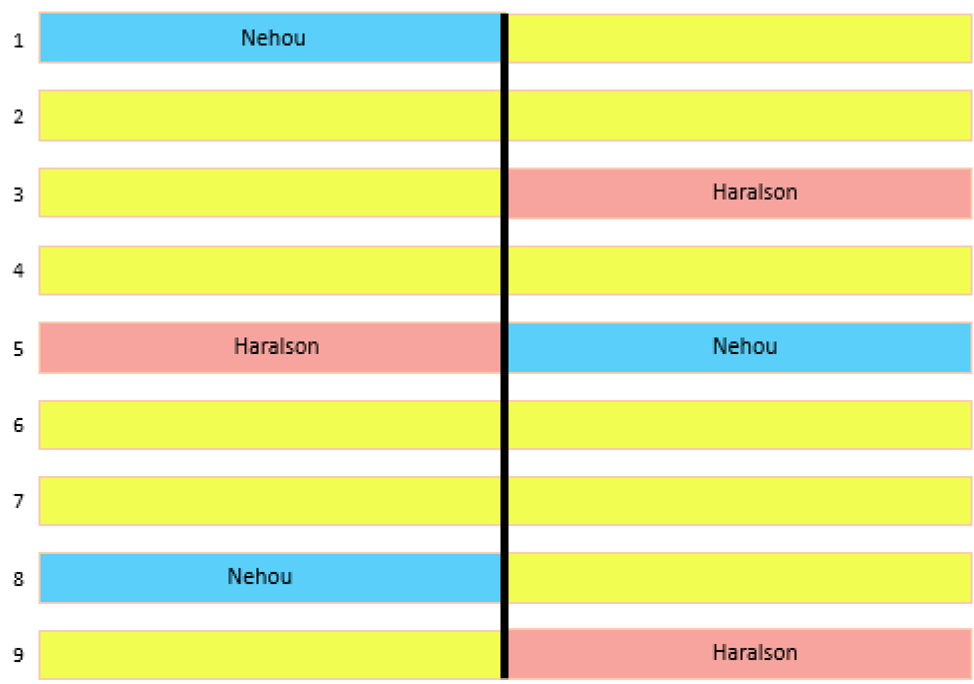


Fig. 1. Aerial view of the cinder block at Cold Spring Orchard. Although there are nine rows with other cultivars of trees we only focused on rows which had Haralson and Nehou varieties that included all three treatments.

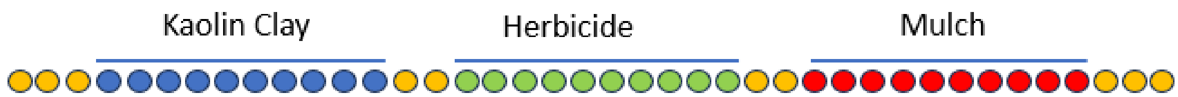


Fig. 2. Aerial view of what a row looks like. Each circle represents one tree. Orange trees act as buffer areas in between treatments to avoid contamination.

2.2 Weed Sampling:

Weeds were sampled three times throughout the summer on June 16th, July 20th, and August ?th. For the samples taken in June and July, a visual scan was done for every tree in rows where the three treatments were applied (rows one, three, five, eight and nine). For the weed experiment only, other cultivars in treatment rows were also sampled. Weeds were given a rating between one and four, with one indicating 'no pressure', two 'little pressure', three 'moderate pressure', and four 'high pressure'. A small plastic bucket was placed around the rootstem of each tree for a consistent survey area of 10 inches in diameter (insert picture after we go to sample the weeds). On August ?th, weeds were removed from the ground and grouped based on their treatment for a total of eighteen bags. After the collection period, weeds were oven-dried overnight and weighed.

2.3 Leaf Sampling:

Leaf sampling began on July 20th. Fifty leaves were sampled from each treatment of each row of trees by walking back and forth. Leaves from the midsection of branches were selected, making sure to sample from different heights and sides of the canopy. This was repeated for all treatments in each row for a total of nine samples per cultivar. Leaves were sent to Waypoint Analytical for further analysis of nutrient contents (N, P, S, K, Ca, Mg, Na, Cu, B, Mn, Zn, Fe, Al).

2.4 Soil Sampling:

Soil sampling was done on July 28th. Soil was gathered by driving a soil auger below the topsoil layer (find diameter). Samples were taken from all ten trees in each treatment for each replicant of both cultivars. Each tree had two sub-sample sites: one that went from the top layer of the soil to a depth of four inches, and one from a depth of four to eight inches. All four inch sub-samples taken from a given ten trees in the same treatment were combined into one unified sample. The same was done for samples taken from four to eight inches. Once combined, the soil was oven dried on a low setting for 24 hours and sent to the Soil and Plant Nutrient Testing Laboratory on the UMass Amherst Campus, where they conducted tests of soil pH, acidity, extractable nutrients (P, K, Ca, Mg, Fe, Mn, Zn, Cu, B), lead, aluminum, cation exchange capacity, and percent base saturation (Soil Sampling Instructions, n.d.). In total, there were thirty-six samples with twelve coming from each treatment.

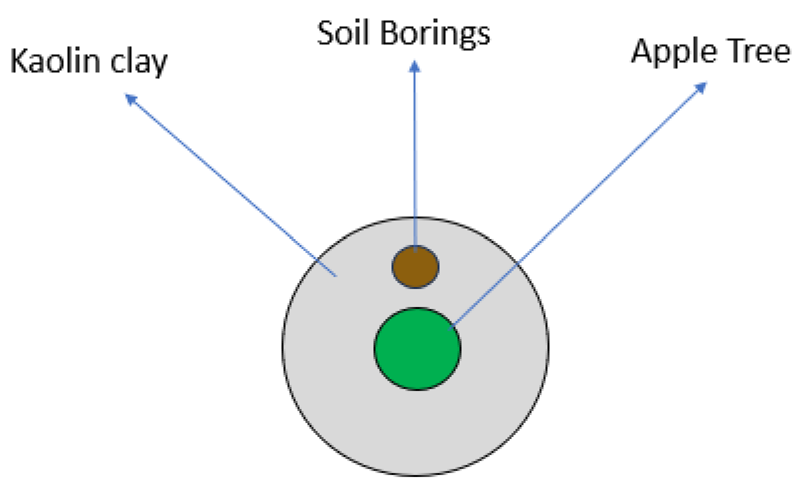


Fig. 3. Diagram of what the sampling process looked like. Soil borings were made roughly three to four inches away from the root stem of each apple tree after the clay was peeled back.

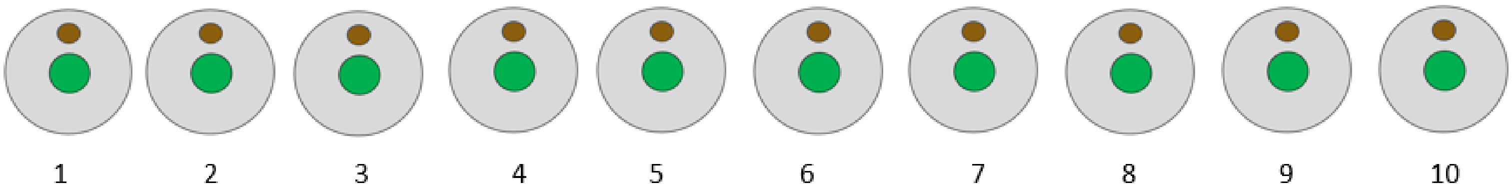


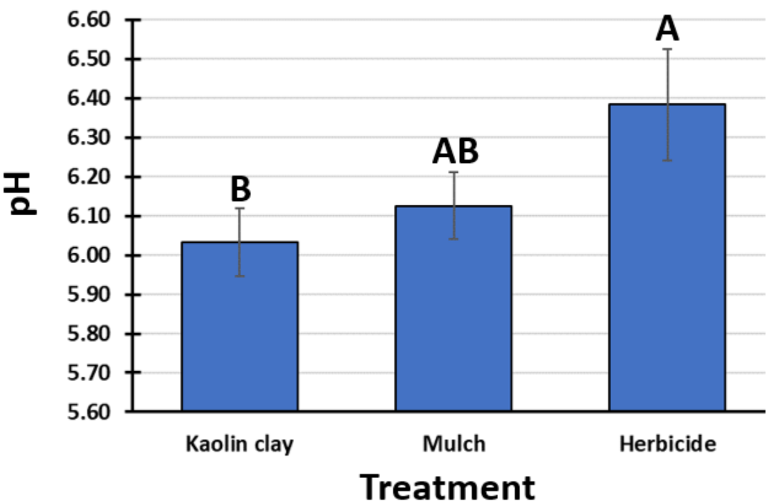
Fig. 4. One treatment of kaolin clay trees after all soil sampling has been done.

3.0 Results:

3.1 Weed Sampling:

3.2 Leaf Sampling:

3.3 Soil Sampling:



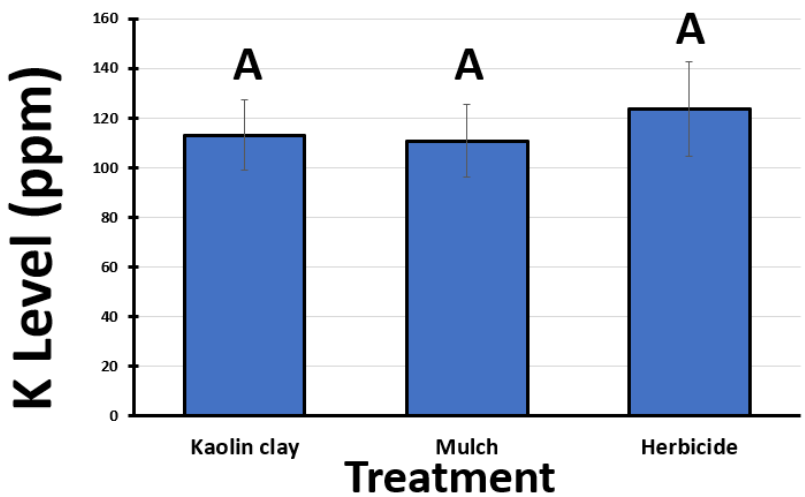
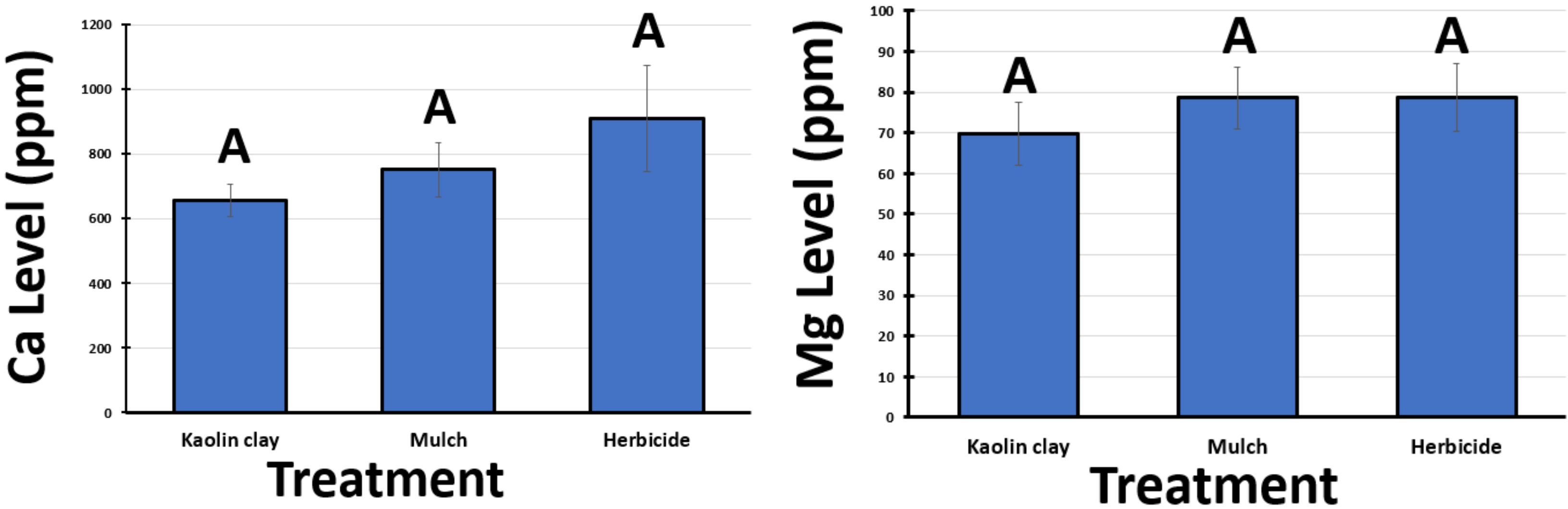
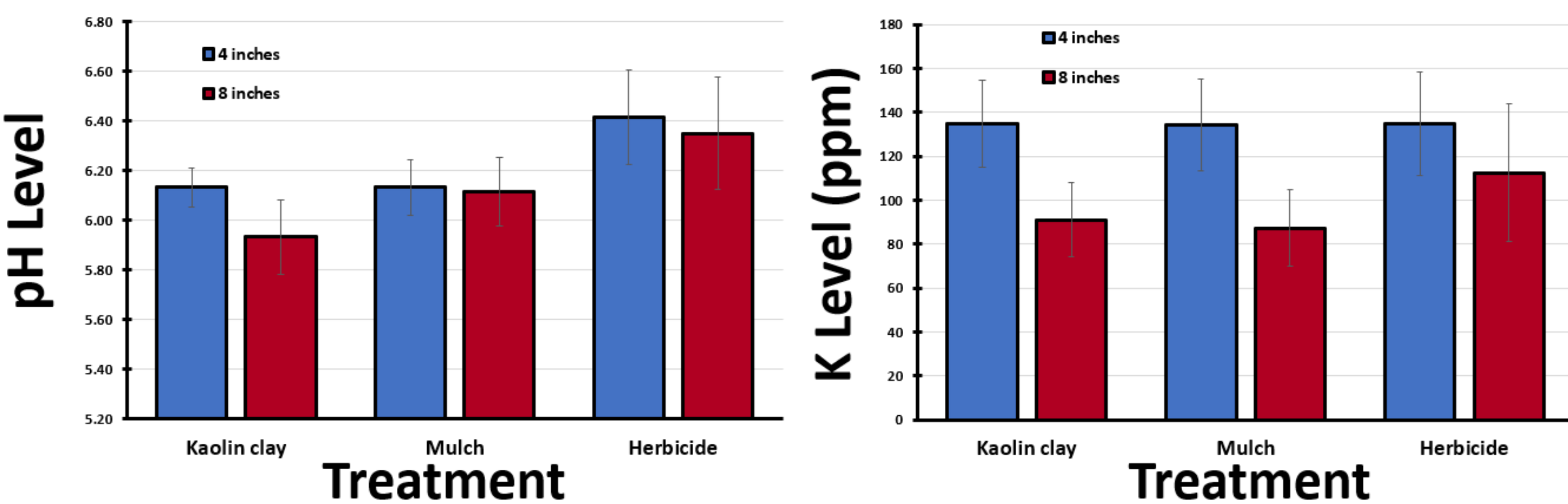


Fig. 5 (left) and 6. When disregarding the depth of samples kaolin clay and herbicide treatments were significantly different from one another when comparing pH levels (ANOVA; p = 0.0384). When comparing potassium (K) levels in soil there were no statistically significant differences between treatments (ANOVA; p = 0.9128).

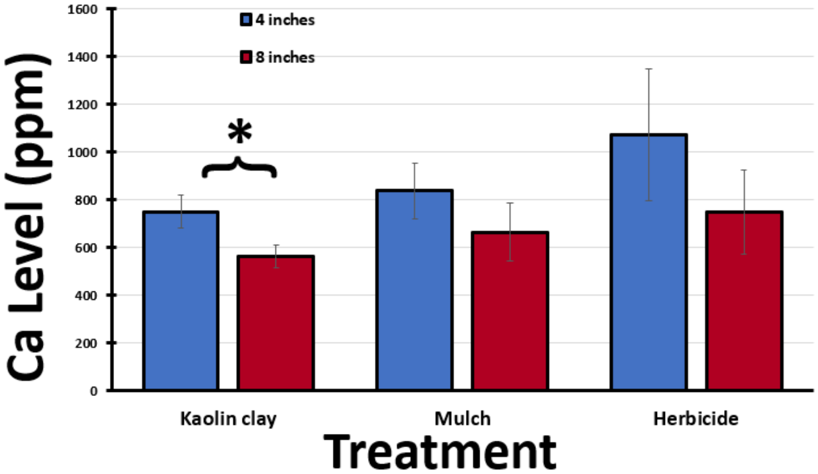


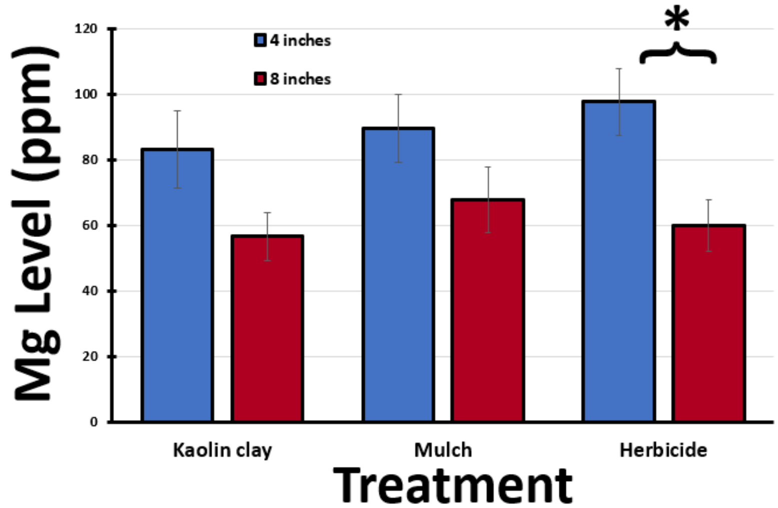
Figures 7 (left) and 8. When disregarding the depth of samples, treatments had no significant effect on calcium (Ca) levels in the soil (ANOVA; $p = 0.583$). When comparing magnesium (Mg) levels in soil there were not significant differences between treatments (ANOVA; $p = 0.7599$).



Figures 9 (left) and 10. When comparing depth in each treatment there were no significant differences in pH level (T-Test; Kaolin clay $p = 0.2665$, Mulch $p = 0.9276$, Herbicide $p = 0.8268$).

There were no significant differences in potassium levels in soil when comparing depth in each treatment (T-Test; Kaolin clay p = 0.104, Mulch p = 0.085, Herbicide p = 0.4667).





Figures 11 (left) and 12. When comparing depth in each treatment there was a significant difference in kaolin clay treatments for calcium (T-Test; Kaolin clay p = 0.0497, Mulch p = 0.3051, Herbicide p = 0.3269). There was a significant difference in the depth of herbicide treatments for magnesium (T-Test; Kaolin clay p = 0.0965, Mulch p = 0.1544, Herbicide p = 0.0117).

4.0 Discussion:

Looking back on how the weed sampling was performed it makes more sense to take soil samples after pulling the weeds out from our three treatments. When sampling the soil the clay had to be removed from the ground temporarily for accessibility. After all the samples were collected the clay was placed back on top of the soil but cracks formed from the removal process. This in turn can allow for more weeds to sprout through the exposed soil in the kaolin clay, potentially skewing the results of our experiment. It is also important to mention that at the time of soil sampling some of the clay already had cracks in it that exposed bare soil. This was most likely due to the swelling and shrinking of the clay during times of rainfall and dry weather (Pengel et al., 2016). Due to time constraints we weren't able to wait until after weed sampling was done because of the time it took to process the results of the soil sampling at the UMass Soil Testing Lab.

The results from the leaf sampling are somewhat scattered and do not reflect what we expected to happen. The point of the leaf sampling in the first place was to determine whether the tree was still able to access macronutrients in the soil; there was the possibility of the clay trapping the nutrients from the tree partially or completely. Leaf sampling in particular is not the best way to find out if a tree is able to uptake nutrients either, since they allocate certain nutrients to different parts of the tree (Hyung-Sug et al., 2011). For example you typically can find high amounts of nitrogen in new leaves as nitrogen is associated with growth of a tree as well as a high concentration of calcium in the cell walls of fruit tissue (Stiles et al., 1991). In order to get a better understanding of the effects of different ground covers we would have to start looking at more parts of each tree like the stems, fruits, branches and roots (Shunfeng et al., 2018). There is also no data prior to the application of each groundcover treatment. We did not take leaf samples before the clay, mulch and herbicides were applied to the ground. There are no trees in the cider plot without ground cover as well so there is no true control treatment. The herbicide acts as a control for this experiment but we would do things differently if given the chance.

Results from the soil samples were also mostly scattered but there were a few trends noted. The most important is the effect each groundcover had on pH levels in the soil. This is important as certain nutrients become more readily available to plants depending on soil pH (Raty et al., 2021). Kaolin clay was significantly different from the herbicide treatments and was found to have a much lower pH. This can be useful knowledge to growers who may be trying to grow fruits that require more acidic soils, like blueberries for example. There were also statistically significant differences when comparing the depth of soil samples. This was anticipated as one typically finds that the lower you dig in the soil the less plant available nutrients you will find. For future experiments we believe it would be better to take samples of the soil only to a depth of four inches, since the clay rests on the top layer of soil and likely does not have an effect down to depths of eight inches in soil yet. If we were to run the experiment much longer, for about seven to ten years, it would then make sense to start testing deeper into the soil as it would give the clay ample time to break down and disperse into lower regions of the soil (Takeda et al., 2005). By only focusing on a depth of four inches we would be able to take more four inch sub-samples allowing for more accurate and precise results. Again, there is also no data prior to the application of each groundcover treatment. We did not take any soil samples before the clay, mulch and herbicides were applied to the ground so the herbicide acts as a control for this experiment. Some of the factors mentioned in the results may only account for small discrepancies in the data, or even none at all. Being a scientist means you have to be thorough and honest about your findings. It is okay to admit uncertainty.

In our experiment we aimed to see if the presence of kaolin clay had an effect on the composition of macronutrients in the soil and leaves of apple trees. Based on the data we can say that there are no significant effects of treatment on the amount of soil and leaf nutrients. However, the effect of treatment on soil pH was significant. The trees planted in the cider block are still young so it will be interesting to see how the clay interacts with trees as they develop. This experiment could lead to some promising results given enough time and a more refined methodology, more work needs to be done in the future.

More broadly, thick groundcovers left in place after harvest also create a physical barrier for litterfall, which could potentially interrupt nutrient cycling (CITE https://link.springer.com/article/10.1007/BF02143038).

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