WARD Laboratories, Inc.

Haney Test Interpretation Guide v1.0

WARD Laboratories, Inc.

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Overview

The Haney Soil Health Test offers a more comprehensive look at the nutrient needs and overall health of your soil system. However, it is not a complete evaluation of your soil's health due to its lack in the direct measuring of some of the other soil health indicators such as bulk density, water infiltration rates or water holding capacity. Some of the items measured by the Haney Soil Health Test are similar to traditional tests. Soil pH and organic matter, for example, are evaluated in the same way as the more traditional soil tests many of you have used in the past. In addition, plant available nutrients such as NPK are evaluated with the same instrumentation. The Haney Test, however, uses different soil extracts, namely H3A and H2O, to determine what quantity of these nutrients are available to the crop and accessible to the microbes. Nitrate, for example, is soluble and there is little difference between various extracts. Other nutrient levels, however, will vary from traditional tests that use different extracts due to the unique ability of each extract to effectively pull nutrients out of the soil. We are currently working on a guide to help producers correlate values from the H3A and H2O extracts of the Haney Test to those of more traditional extracts such as Mehlich III, Bray P1, Ammonium Acetate, DTPA and others.

The Haney Test differs from traditional soil tests in that it also evaluates some soil health indicators such as soil respiration, the water-soluble fractions of organic carbon and organic nitrogen and the ratio between them. Finally, a soil health score is calculated based on a combination of these different soil health indicators. Below is a guideline for understanding and interpreting some of these different values.

Soil Respiration

The respiration test is aimed at measuring the amount of CO2-C a soil can produce over a 24hr incubation period following a significant drying and rewetting event. In other words, how much does your soil breathe when conditions are optimal? Most microbes produce CO2 through aerobic respiration just as we do and the more CO2 a soil produces the more life it contains or the higher the microbial biomass. This is important because it relates to a soil's potential for microbial activity, which is tied to many functions of a healthy soil such as nutrient cycling, soil aggregate and organic matter formation, disease suppression and stimulation of plant growth.

Soil respiration readings can fall anywhere from near zero to 1000 ppm of CO2-C. However, most agricultural soils are currently degraded and do not read above 200 ppm. In general, the higher the number the better, but this can have an effect on subsequent management decisions. For example, a soil with a very low score may exhibit symptoms of slow residue breakdown. On the other hand, residue may cycle very quickly in soil with a high score. Therefore, residue management strategies and

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the soil respiration score one might strive for are going to be dependent on the type of production system you find yourself in.

Below is a table showing the rankings as they relate to soil respiration. These rankings are based on my own observations and the observations shared with me by others. While I feel that these descriptions fit a lot of different production scenarios, they will not necessarily fit each unique situation. In any case, however, soil respiration is considered a strong indicator of overall soil biological function.

Soil Respiration Ranking Table

CO2-C in ppm	Ranking	Implications
0-10	Very Low	Very little potential for microbial activity; slow nutrient cycling and residue decomposition; high carbon residue may last >2-3 yrs. with limited moisture; Nearly no N credit given; Additional N may be required due to microbial immobilization
11-20	Low	Minimal potential for nutrient cycling; residue management can still be a problem; Very little to no N credit given
21-30	Below Average	Some potential for nutrient cycling; residue management can still be a problem with prolonged use of high carbon crops; Little N credit given
31-50	Slightly Below Average	Low to moderate potential for microbial activity; Some N credit may be given
51-70	Slightly Above Average	Moderate potential for microbial activity; Moderate N credit may be given; May be able to start reducing some N fertilizer application
71-100	Above Average	Good potential for microbial activity; Moderate N credit may be given depending on size of organic N pool; Can typically reduce N application rates
101-200	High	High potential for microbial activity; more carbon inputs may be needed to sustain microbial biomass; moderate to high N credit from available organic N pools may be given; N fertilizer reduction can be substantial
>201	Very High	High to very high potential for microbial activity; residue decomposition may be <1 yr.; keeping the soil covered could be a problem in some systems; high potential for N mineralization and N credits from available organic N pools may be given; N fertilizer reduction can be substantial

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You will notice that no 'true' average is given in the table above because the rankings are on a sliding scale and are somewhat dependent on soil type and climate region. Soil and farm management does, however, influence soil respiration scores regardless of what type of soil and climate one has to work with, but much like yield potential, we must work within reasonable expectations for a given area. In general, cold or arid climates and/or sandy or extremely high clay soils will not usually perform as well as regions with abundant moisture and/or a longer growing season. For example, a soil that has a respiration reading of 50 from New Mexico might be interpreted as above average or even high for that region. Whereas a soil that scores the same from central Iowa might be interpreted as below average for that region. A soil that scores below 10 or above 200 is considered to be very low or very high, respectively, regardless of these other aforementioned factors.

Soil respiration values can change with the growing season and environmental conditions. The variability or swings in respiration values are typically greater in poor to marginal soils due to these soils having less ability to buffer against disturbance and times of fewer carbon inputs such as fallow periods. On the other hand, soils that are healthier often exhibit the ability to sustain a higher microbial biomass or respiration value during times of drought or extreme temperature. In other words, a healthy soil becomes more resilient to environmental conditions and disturbance. In either case, it is important to sample at the same general time each year or at least under the same general soil conditions, especially when tracking change in soil respiration over time as an indicator of overall progress.

Water Extractable Organic Carbon

The water extractable organic carbon or WEOC is a measure of the organic carbon or food that is most readily available to the microbes. The WEOC is a smaller fraction of the total soil organic matter (SOM). The size of this pool can reflect the quality, rather than just the quantity, of the organic matter present in your soil system. Generally, the higher the number the better because there is more food or energy available to drive the microbial system. However, we want there to be a good balance with organic nitrogen as you will see covered in the sections below. There is not necessarily a direct relationship to organic matter content. We see soils with 2% SOM have over 400 ppm of WEOC and soils with 4% SOM have less than 200 ppm WEOC. However, it is more difficult to sustain a larger pool of WEOC without a moderate to high level of SOM.

Most agronomic soils that we have tested so far fall in the range of 50 to 800 ppm with a majority of those soils falling between 100 and 300 ppm. Typically native and perennial systems have higher WEOC values compared to row crop systems. This does not mean, however, that row crop systems cannot achieve higher values for WEOC. Inputs such as manure, compost or cover crops can increase carbon loading and cycling leading to higher WEOC levels.

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WEOC values also fluctuate throughout the year. Typically, in late winter and early spring we see values climb as freezing and thawing events help with mechanical breakdown residues and the release of carbon from soil aggregates. There is less microbial activity this time of year across many regions due to colder soil temperatures and the carbon is allowed to build up in the system. As soil temperatures rise in the spring we usually see a dip in WEOC values because microbes are utilizing this food source faster than it is being resupplied to the soil. As we move into the growing season plant roots begin to leak more carbon into the system and we see a slow increase in WEOC until soils reach an equilibrium between carbon supply from the growing plants and past crop residues and microbial consumption. When annual crops reach maturity in late summer to early fall there is a large carbon influx from the roots due to root sloughing and the eventual breakdown of the root system. The WEOC values will then slowly decline as soils cool or moisture becomes more limited and the microbial activity slows to start the cycle over again through winter. Exactly when and how long each of these phases will last depends on your current soil health level, growing season, overall climate and production system. Furthermore, this cycle is more pronounced in conventional row crop systems.

Microbially Active Carbon (%MAC)

Microbially active carbon or %MAC is how much of the WEOC pool was acted upon by the microbes measured as soil respiration. If this value is below 25% this tells you that WEOC is probably not the factor limiting your soil respiration. Perhaps it is the soil's overall fertility, prolonged cold temps or drought that is limiting microbial biomass. On the other hand, if the %MAC value is above 80% this might tell you that WEOC could become limiting to microbial respiration soon and your management focus should be on introducing more carbon into the system. Ideally, I like to see a %MAC value between 50 and 75% for most production systems. This generally tells you that the soil has a good balance of fertility and WEOC to support microbial biomass, but you are not limited by your WEOC pool. This value, however, should be taken into context and we still need to look at the respiration and WEOC individually to gain a better understanding of the overall status of your soil.

Water Extractable Organic Nitrogen

The water extractable organic nitrogen or WEON represents the pool of organic N that is available to the microbes. Think of organic N as amino acids and proteins, which are linked to the carbon or food that the microbes are eating. Much in the same way we measure protein in the foodstuff for livestock, the Haney Test is measuring the amount of protein available to the microbes. Feeding the microbes an N rich food source, such as manure or a low C:N ratio cover crop, allows them to better carry out many important functions in the soil that can benefit the crop and your pocketbook. One of these functions is N mineralization or the conversion of organic N into plant available forms such as nitrate and

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ammonium. In a healthy soil with greater biological function this can lead to a reduced need for synthetic N fertilizer.

We have found soils to contain anywhere from 5 to 100 ppm WEON with a majority of soils falling between 10 and 30 ppm. Remember that 30 ppm is equivalent to nearly 60 lbs of N to the acre at a 6-inch sample depth. As with the WEOC, the higher the value the better in most situations, but we do not want to disrupt the balance between WEOC and WEON.

Organic C to Organic N Ratio

This is the balance between the WEOC and WEON and it is expressed as the C:N ratio on the Haney Test report. Organic C and organic N are intimately tied together, and both are required to help get the optimal function out of your soil system. A soil that has very high WEOC with little WEON has a lot of energy present for the microbes, but the quality or nutrition of that food is low. Think of an energy drink or feeding wheat straw to cattle. On the other hand, a soil with very low WEOC and high WEON has a lot of N available to the microbes but very little energy value to help carry out important functions. Think of a multivitamin or feeding only a mineral supplement to cattle. All living things require a balance of energy and nutrition.

It is very important to note that there are a lot of different C:N ratios discussed in agriculture. This particular C:N ratio is that of the water extract performed as part of the Haney Test. This ratio is not the same as the total C:N ratio of your soil or the manure or cover crop you are using or even the C:N ratio of the organic matter in your soil. Decomposition and breakdown by microbes reduces the C:N ratio of the starting material. For example, corn stover has a C:N ratio of nearly 60:1. On the other hand, SOM has a C:N ratio between 10:1 and 12:1. If the corn stover is going to become part of the soil organic matter the microbes have to break it down to a ratio of nearly 10:1. They achieve this by converting carbon in the corn stover into microbial biomass and by releasing most of the carbon as CO2 (remember soil respiration). The water extract on the Haney Test is measuring part of this transitional process between the initial breakdown of residues and the product of more stable SOM. The higher the starting C:N ratio generally the longer it takes to accomplish this goal. This is one reason why high carbon crop residue lasts longer in your fields than low carbon residue. We can use lower C:N ratio inputs such as manure and legume/brassica cover crops to help speed this process or we can use higher C:N ratio inputs to slow this process. We will discuss this more in another section below.

Below is a table showing the rankings as they relate to the C:N ratio. The management needs listed are not the only solutions used in correcting for or maintaining the desired C:N ratio, but these are some of the more popular methods when overall soil health is the goal in mind.

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Organic C:N Ratio Ranking Table

Ratio Result	Ranking	N Implications	Management Needs
>20:1	Poor; Too much organic C and/or not enough organic N	N tie up by microbes: No N credit given from WEON pool	Increase legumes in rotation or covers; reduce high carbon inputs; graze longer to reduce carbon
Between 15:1 – 20:1	Marginal	Some N tie up; Slower mineralization; Lower N credit from WEON	Increase legumes in rotation or covers; reduce high carbon inputs; graze longer to reduce carbon
Between 8:1 – 15:1	Good	Less N tie up; greater potential for N mineralization; higher credit from WEON	Make slight adjustments if near the boundaries to keep within this range
Between 10:1 – 12:1	Ideal	Greatest potential for N mineralization from WEON pool; good balance of available energy and N for microbes	Increase intensity to drive both WEOC and WEON up together to help increase biological processes
<8:1	Poor; Too little organic C and/or too much organic N	Limited energy for microbial activity; N credit may still be high if soil respiration and WEON are also high	Increase carbon inputs; graze shorter to retain carbon

Organic N to Inorganic N Ratio

Nitrogen in your soil is found in either the organic or inorganic form. Inorganic N is usually referred to as plant available N and is often in the form of nitrate and ammonium. On the other hand, organically bound N is typically only discussed within the collective context of soil organic matter. While it is true that organic matter contains a relatively large amount of organic N at nearly 1000 lbs for every 1% SOM, most of this N is relatively stable and hard to access by soil microbes, especially within a time frame that is helpful to the growing crop. More importantly, if we mine N from the SOM we must destroy the SOM. This is like trying to remove all the nails and screws that hold together your house, and to be successful, we must destroy much of the house. There is, however, a source of organic N that is in transition between plant and animal residues and stable SOM and that is the pool measured by the water extract on the Haney Test.

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Most agriculture systems are out of balance when it comes to the relative amount of organic and inorganic N present in the soil. Agricultural practices have focused on large additions of inorganic N as fertilizers to increase production and yield. While this system has undoubtedly worked to boost crop yields, it has come with many costs to both your soils and the environment, not to mention your pocketbook. Overall, it is not a very efficient system and a lot of the N applied never makes it into the crop. I am not, however, saying that we should collectively stop applying N fertilizer, but there is a better way to utilize what you are paying for in fertilizer and reduce the overall need for large N fertilizer applications.

Soil systems that are highly dependent on N fertilizer additions will often exhibit a ratio below 1 between organic and inorganic N. This means that much of the N present in the soil exists as nitrate and ammonium. Microbes can utilize these sources of N, but this often results in N immobilization or tie up that is taking N from your growing crop. Soil management systems that focus on soil health and holistic management start to build an organic N pool that is greater than the residual inorganic N left in the soil. This is often done by varying crop rotations and the use of cover crops. In these systems, we start to see ratios climb above 2 and 3. I like to see the ratio above 5 and the higher the number the better. Remember that organic N, when balanced with organic C, is what helps fuel the biological system, which will in turn help feed the plants leading to a more efficient use of N.

Organic N Release

The organic N release is the overall N credit given to your soil based on the parameters listed above. If the C:N ratio is balanced, then the amount of credit given will be dependent on the soil respiration score and the size of the WEON pool. The higher the respiration the more microbes present in the soil and the greater the potential for activity and N mineralization. Furthermore, the higher the WEON the greater the potential for release because there is more N for the microbes to access. The organic N release credit on the Haney Test, however, will never be greater than the amount of N measured in the WEON pool regardless of the C:N ratio or the respiration score. This credit is subtracted from the recommended N needed to produce the next crop based on the crop and yield goals provided by the producer.

The organic N release value is expressed in ppm, but this value can be converted to a credit shown in lbs per acre using the following equation:

Sample depth in inches * 0.3 * ppm value for organic N release = lbs of N released per A

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For example, a sample of a depth of 0-6 inches and an organic N release value of 30 ppm would be calculated as 6*0.3*30 = 54 lbs of N per A credit from the WEON pool. An 8-inch sample with the same 30 ppm value would equal 72 lbs of N per A. Therefore, the Haney Test is measuring another N credit from your soil that the more conventional tests utilizing only nitrate or ammonium do not account for. In some cases, especially with soils that are deemed as unhealthy, this credit is minimal and may not have an impact on the amount of N fertilizer required. However, in very healthy and highly functioning biologically active soils this credit can have a real impact on crop production and reduced N fertility needs. In other words, some of the time, effort and money spent on making your soil better is paying you back with savings on N fertilizer.

You can see the difference between a conventional test that typically only measures nitrate as an N soil credit and the total N credits provided by the Haney Test by looking at the 'Traditional N Evaluation', 'Haney Test N Evaluation' and the 'Lbs of N Difference' values on the second page of the PDF report.

Organic N Reserve

The organic N reserve is how much of the measured WEON pool is left following the credit given for organic N release. Don't panic if you see a value of '0' here. This simply tells you that you maximized your N credit from the WEON pool. A '0' does tell us, however, that if you were able to increase the size of your WEON pool, that you would likely get a larger credit. On the other hand, if you have a number other than '0' left in your reserve, then this tells you that if you had a larger microbial biomass (soil respiration) or a more balanced C:N ratio that you could likely get a higher credit on the release.

The soil is constantly refilling this pool with organic N by the continued breakdown and cycling of plant and animal residues. Remember, however, that you can help this process based on your management decisions and the constant addition of fresh residues. It is a systems approach to building soil.

Soil Health Score

The soil health score is a summary of the soil respiration, WEOC and WEON measured by the Haney Test and represents the current health level of your soil based on these indicators. The score is aimed at providing a producer a quick reference regarding the health of their soil compared to other soils under different types of management. The score can range anywhere from 0 to 50, but most soils do not score higher than 30. In general, the higher the score the better. We like to see the score above 7, but 7 is simply a starting point. To get a better understanding of what your score is telling you we have to make comparisons between different land managements, soil types and climatic regions.

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Much like soil respiration, land management has a profound effect on the soil health score, but it is still somewhat limited by regional constraints. Using the same example from New Mexico and Iowa above, it would be unfair to say that a soil scoring a 7 from both regions would in fact mean that both producers are performing equally well in regards to soil health using this test. A soil in New Mexico likely has a much lower soil health score potential due to environmental factors and differences in soil type whereas the soil in Iowa may have a much greater potential under the same management. The best way to determine your own potential is to find a soil in your immediate area that you believe is the poorest and one that you deem as the best. I would encourage you to look beyond yield when determining the poorest and the best soils because yield is not necessarily a strong indicator of soil health. Rather I would focus on management and ecosystem type. Perhaps a soil that is tilled too often or has a very narrow crop rotation would be classified as poor and a soil that is relatively undisturbed or native with a lot of diversity would be deemed as good. Running a test or two from these soils along with your fields of interest will help provide you potential ranges on the bottom and top end for your region. Hopefully, your soil will fall closer to the top end, but if it doesn't, it allows you to set some management goals with realistic expectations when it comes to what you can achieve on your own farms using the Haney Test.

Cover Crop Recommendation

The cover crop recommendation is a very general guideline for helping you balance your soil system based on some of the various numbers on the Haney Test. It is nearly impossible to provide anyone with a specific cover crop recommendation due to the large number of variables that must be considered, such as the equipment and seed available, crop rotation, climate, etc. However, we can give some suggestions for the producer starting out and wanting to know where to begin.

The percentage of grass to legumes/brassicas is based on two factors. First is the C:N ratio. If the ratio is below 8:1, then we are going to suggest a higher percentage of grasses to help increase the amount of carbon going into the system. On the other hand, if the ratio is above 20:1, then we are going to suggest a higher percentage of legumes to help provide you with the organic N needed to help you start the residue decomposition and nutrient cycling processes. If your C:N ratio falls in the desired range, then we base the mix of grasses to legumes from the soil health score. The number one factor going into the soil health score is soil respiration. Remember that respiration is an indicator of living microbial biomass. Therefore, if you have a high soil health score you likely have a high respiration value, meaning more microbes to feed and your soil's need for additional carbon inputs is greater. This leads to a higher amount of grass being recommended in the mix. If your soil health score and respiration is relatively low, but you are still balanced for C:N, then we want to add more legumes and brassicas because you have less microbes available to breakdown residue.

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The best analogy that I have been able to come up with is that building a biologically active and highly functioning soil is similar to building a good fire. If you are just starting out, you have to make sure that you have the right type and balance of fuel. In addition, you must be careful not to put too much fuel on the fire at the very beginning or you will smother the fire. In other words, too much high carbon residue is hard to breakdown quickly early on in your soil health journey and we don't want to bury your soil, microbes and growing crop in too much residue. So, the answer is to start with crops or covers that have a relatively low C:N ratio and try not to produce a cover that is 8 feet tall. I need to mention, however, additional management decisions such as grazing can affect your approach on this as well because you can use the livestock as a wonderful tool to help manage your residue. Back to the fire. As your fire slowly builds or as your soils start to increase microbial biomass so does the demand for fuel or carbon. Now you can start increasing the amount of high carbon crops that are being introduced to the system and you can start trying to grow more biomass or letting covers get closer to maturity if time allows. Use your own observations to determine if residues are sticking around too long or disappearing before your eyes and make adjustments as necessary to your mix. Once the system is really ramped up and you have a raging fire on your hands, you might find it difficult to keep residue around as long as you wish it did. This isn't all bad, however, as you now know that your biological system is really working for you. You are now cycling nutrients, building and rebuilding soil aggregates, infiltrating and holding more water, getting better root growth and a more efficient use of your nutrients all at a lower cost in time and money.

Additional information is available on the website at www.wardlab.com and new information may be added as it becomes available. Any questions regarding soil health testing may be directed to biotesting@wardlab.com.

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