INSPECTION AND DATA COLLECTION PROTOCOL TO MONITOR PERFORMANCE OF BIOTIC SOIL TECHNOLOGY

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Abstract:

One vexing issue facing successful restoration of disturbed sites is lack of available topsoil to create viable environments for establishing sustainable vegetation. In the absence of adequate sources of topsoil, new techniques have been developed to treat and revive depleted soils to render them more capable of accelerating and sustaining vegetative growth. Essentially, on-site soils can be "engineered" to improve their physical and biological properties. The meticulous introduction of organic matter, agronomic amendments, plant biostimulants and soil building components can effectively turn marginal soils into productive and sustainable growth media. Biotic Soil Technology (BST) is a generic term to describe the emerging field of manufactured growth media containing biodegradable fibers, biostimulants, biological inoculants and other components engineered to cost-effectively increase organic content, accelerate vegetative establishment, maintain a sustainable growing environment and promote regeneration of denuded soils.

BSTs offer several advantages over field harvested soils and their replacements, including compost. They are produced under highly controlled conditions to ensure consistent quality control/quality assurance, elimination of weed seeds, pathogens, insects, phyto-toxins and contaminants with documented legacy of environmental safety. Further, ease of application through conventional hydraulic seeding and mulching equipment make BST an effective complement or replacement for topsoil – thus reducing quantity requirements and costs while improving project success. BSTs are typically placed as a growth media layer beneath various erosion control techniques such as hydraulically-applied or rolled products, blown straw/hay or even sod.

The efficacy of BSTs is becoming more fully demonstrated with a growing portfolio of successful installations around the world on a variety of challenging sites involving highways, airfields, commercial and residential construction as well as engineered cover systems for mining, waste containment and more. Beyond the initial mission to cost effectively foster more rapid and complete establishment of vegetation to reduce erosion and improve water quality, there is a need to monitor changes in organic matter levels, soil pH, microbial levels and other parameters that contribute to sustainable growing environments.

This publication will offer prescribed testing protocol for site assessments prior to installation to determine suitable BSTs, agronomic amendments and their application rates. Next, protocol will be offered for inspection techniques during installation, post-installation monitoring of vegetative species composition, density and cover, and laboratory testing to document changes in soil chemistry, structure and biota over time. Case studies of two projects will serve as examples to demonstrate the testing protocol, sampling methodology and results obtained.

Introduction:

Biotic Soil Technology (BST) is a generic term to represent the emerging field of manufactured growth media containing naturally derived biodegradable fibers, biostimulants, biological inoculants, soil building components and other amendments designed to accelerate sustainable vegetative establishment, increase organic matter content and promote regeneration of denuded soils. BSTs have been engineered as cost effective alternatives and/or complements to soil, compost and other materials prescribed when on-site soils are lacking in organic matter or have little to no biological activity and high-quality topsoil is unavailable or too costly to import. BSTs are engineered to foster development of topsoil in deficient substrates within the rhizosphere – the region of soil where plant roots are concentrated, and the soil's chemistry and microbiology is influenced by their growth, respiration, and nutrient exchange. This in turn promotes faster seed germination and growth, which initiates the long-term nutrient cycling that ultimately enhances and assures a sustainable vegetative cover (Theisen and Robeson, 2017).

BSTs also contain components that increase the water and nutrient holding capacity of soils while creating a more ideal environment for growth of beneficial microorganisms to allow for faster seed germination and vegetation establishment. Unlike field harvested topsoil, sub-soils and compost; these materials are manufactured under controlled conditions with specific formulations that ensure product quality and consistency. BSTs are typically mixed with water and are hydraulically-applied as a uniform slurry using standard hydraulic seeding and mulching equipment; offering the distinct advantage of also placing seed, fertilizer and other soil amendments in one convenient and more rapid application. Although BSTs are capable of offering a moderate level of erosion protection, they are normally covered with hydraulically-applied or rolled erosion control products, blown straw/hay, sod or other erosion control techniques.

Site Assessments:

A site assessment is a mandatory requisite for selection of appropriate BSTs and complementary erosion control techniques prior to proceeding on any revegetation or restoration project. Testing of representative in situ or imported soils and substrates should be conducted by an accredited lab to determine their agronomic potential. Key parameters should include soil pH, texture, percent organic matter, availability of macro- and micro-nutrients, Cation Exchange Capacity (CEC), Total Dissolved Salts (TDS), and monitoring for excesses of potentially toxic constituents such as heavy metals, chemicals, or other contaminants. Relevant testing protocol and methodologies for erosion control projects that require vegetative establishment are described in detail in a technical primer for Soil Testing and Interpretation that also provides optimal ranges for various soil parameters and values where deficiencies or excesses may compromise or limit vegetative establishment (Profile Products Technical Document, 2015).

Organic Matter (OM) is largely made up of carbon that originated from living organisms and dead material and is of profound importance for soil function greatly impacting its physical, biological and chemical properties. OM acts as a long-term carbon sink and as a slow-release pool for nutrients contributing to CEC, nutrient cycling, soil aggregation and water holding capacity. Stabilized organic matter contributes to soil function in numerous ways, including those related to soil structure such as its capacity to store water and thus provide drought resistance (Schindelbeck, R.R., et al. Cornell University, 2017).

It is widely accepted that soils capable of supporting sustainable vegetation should contain at least 5% organic matter (US Department of Agriculture, 2013). Thus, BST application rates are typically based on % Organic Matter of a soil or substrate as shown:

Table 1 – BST Application Rates versus % Organic Matter

% Organic Matter	Rate (kg/ha)	Rate (lb/acre)
< 0.75	5,600	5,000
≥ 0.75 & < 1.5	5,040	4,500
≥ 1.5 & < 2.0	4,480	4,000
≥ 2.0 & < 5.0	3,920	3,500

Selection of erosion control products should be based upon proven and reliable design protocol, procedures or laboratory testing employing the Revised Universal Soil Loss Equation (RUSLE) for slopes and Manning's Equation or the Tractive Force Method to determine maximum permissible velocity or shear stress for channelized flow conditions (Profile Soil Solutions Software, 2013).

The objective of a site assessment is to ensure BSTs and any additional erosion control practices are evaluated to determine whether or not the manufacturers' minimum recommended rates are sufficient to prevent erosion, allow a sufficient stand of vegetation, and provide an adequate functional longevity on a given slope (South Carolina Department of Transportation, 2016).

Key Post-Installation Inspection and Monitoring Considerations:

As with any relatively new concept – designers, users and owners want to feel confident in long-term efficacy when considering the use of BSTs to treat soils deficient in OM and nutritive value. When assessing performance of BSTs (as well as the status quo of topsoil), there are several parameters to monitor and measure. The following considerations can be employed to evaluate BSTs on test sites or actual projects.

Site Conditions:

Ideally, the following site conditions are consistent throughout to ensure consistent evaluations.

- The plots tested have the same slope gradient.
- The plots tested have a uniform slope.
- The plots tested have the same slope length.
- The plots have the same aspect for sun exposure.
- The soil type is uniform for all plots tested.
- The soil amendment and fertilizer applications are the same for all test plots.
- The seeding schedule, seed rates and application method are the same for all test plots.
- Mulches are applied at the minimum recommended manufacturers' rates for the given slope gradient and slope length.
- A manufacturers' representative is onsite and provides written approval of the application.
- An automatic rain gauge is installed at the site and records rainfall amounts and the date. If the site is remote and an automated gauge is not possible, a regular gauge is installed and the rainfall is recorded weekly or after every rainfall event.

Field Test Data:

Field test data is collected after each rainfall event and periodically, to the maximum extent feasible. The collected field data is used to compare the performance for each of the applied techniques. A minimum of 5 digital pictures are taken for each plot to verify the data collection results. The following data is recorded for the field test.

- All BSTs, hydraulic mulches and erosion prevention measures installed.
- Plot size.
- Slope height.
- Slope length.
- Slope gradient.
- Soil test results.
- Soil amendment and fertilizer types/application rates.
- Seeding schedule, seed rates and method of application.
- Observed and compared erosion for each plot.
- Observed and compared vegetation establishment for each plot.
- Observed and compared functional longevity for each plot.
- Site and weather conditions prior to and at time of installation.
- Precipitation received since the last data collection.

Soil Properties:

As previously discussed, ongoing testing of representative site soils should be conducted by an accredited laboratory to determine their agronomic potential and to monitor key parameters such as soil pH, texture, percent OM, availability of macro- and micro-nutrients, CEC, and TDS. Subsequent tests should be taken over the first few growing seasons to document changes in soil make up and chemistry.

Vegetative Establishment:

There are several ways to assess vegetative establishment. Percent basal area cover is the most common barometer and often employed by regulatory agencies and others as a basis for release from project requirements, warranties and surety bonds typically resulting in a Notice of Termination (NOT). However, there are other key considerations when assessing vegetative establishment such as species diversity or percentage of desirable species. Those monitoring sites must have the ability to capably identify vegetation to ensure the site does not contain an overabundance of weedy, invasive or cover crop species that will compete with more desirable perennial species that will provide long-term erosion protection.

Beyond species composition and amount of cover, changes in biomass or productivity of a site are also important to monitor. Ideally the amount of biomass would increase over a time horizon to indicate sustainability of a site and/or ecological succession to a climax community or at least a functioning plant community consistent with management practices for the location. For example, roadsides, waste containment or landfill caps, as well as dams and levees must be routinely mowed to discourage establishment of deep-rooted tree and shrub species. Thus, the acceptable level of biomass increase would be predicated on a variety of anticipated environmental or land use factors specific to the site using surrounding representative vegetation as a baseline.

An overabundance of weeds or temporary cover species can disrupt this natural progression and could result in peaks and spikes in biomass and vegetative cover. That is why species diversity and biomass should both be closely monitored and their interrelationship clearly understood. Not only is selection of proper plant species critical to incorporate into an erosion control plan, but their individual seeding/planting rates are also important. When employing BST it may be advisable to lower seeding rates of fast growing temporary cover species or even eliminate them from the seed mixture.

Erosion Control Effectiveness:

While more rapid establishment of verdant and sustainable vegetation are vital to performance, BSTs and supplemental erosion control measures should be inspected and monitored during installation through vegetative establishment. It is imperative the project design ensures adequate erosion measures are employed, particularly on steep slopes and areas of concentrated hydraulic flow. Inspectors should be knowledgeable of all BST mixing and application guidelines in addition to prescribed application rates and their visual appearance.

Supplemental erosion control measures should be employed using agency, engineer, manufacturer or other scientific design and selection criteria. The installations should be in accordance with specifier or manufacturer procedures and carefully inspected and monitored from time of installation until sufficient cover is developed or the site has reached mutual expectations. Sites should be monitored for signs of erosion and maintained after each significant precipitation or other potentially damaging event. Key observed criteria include the type of erosion (scour, rill, or gully), depth of erosion and amount of deposition behind or within sediment control/containment structures.

Case Study #1 - Rehabilitation of Abandoned Residential Site Development:

A 1.1 hectare (2.7 acre) home development site sat abandoned in rural Tallassee, Alabama after it was forced into foreclosure in 2009. As the heavily eroded site began to wash away and impact stormwater quality, the Alabama Department of Environmental Management (ADEM) pressed its owner for stabilization.

Contractor Hunter Bruce, P.E. and owner of SpreadRite, LLC was tasked to engineer and implement a quick and cost-effective solution to remedy the situation and allow the owner to achieve its Notice of Termination (NOT) from ADEM. Initial site assessments determined the site to be highly denuded and devoid of topsoil with significant erosion and discharges of turbid water leaving the site. The contractor’s first step was to obtain soil tests to examine the viability of the site substrates and determine remedial actions to create a suitable environment for growth establishment and effective erosion control.

Soil test results confirmed very low OM ($\leq$1%), acidic conditions and a lack of available nutrients to support growth of vegetation. The contractor’s first option to improve site conditions was to identify a nearby source of high-quality topsoil to accommodate a 10 cm (4 inch) depth over the re-graded substrate. A second option was to consider using BSTs to add OM, biostimulants and other soil building components directly to the denuded substrate.

Figure 1 – Denuded and barren site conditions

Figure 2 – Acidic soils with low organic matter

A detailed cost analysis determined an estimated installed cost of $35.83/cubic meter ($27.41/cubic yard) for a topsoil source located just 0.8 kilometers (½ mile) from the site. Further, the contractor speculated 66 truckloads (assuming 22 US tons per truckload) and 4 to 5 days would be required to harvest, transport, spread and grade the topsoil over the 1.1 hectare (2.7 acre) site. When assessing the BST alternative, an application rate of 5,040 kg/ha (4,500 lb/ac) was considered in the cost analysis as prescribed for the organic matter levels averaging only 1% versus an ideal goal of 5% for sustainable growth. The estimated installed cost of the BST was $29,508; representing a savings of $10,620; or nearly 1/4 of the total estimated cost of $40,128 to place the topsoil.

Moreover, BST can be hydraulically-applied through conventional hydroseeding and mulching equipment along with seed, fertilizer and prescribed soil amendments in one cost efficient application. Hydraulically-applied, dry-applied or even rolled erosion control products are then placed over the BST for added protection from erosive forces as would also be required to protect topsoil as dictated by site conditions. Thus, BST can reduce topsoil and even compost costs while dramatically reducing installation time. For these reasons the contractor elected to pursue the BST option.

Grading of the site substrate to remove gullies, rills and prepare the seedbed commenced in Mid-March of 2015. The flatter areas were leveled and left in a rough condition while the slopes were cat tracked to reduce potential runoff creating pockets and ridges to hold water and seed for quicker growth. Installation of the BST, seed, and soil amendments as well as all erosion and sediment control measures was completed on March 25 in just one day.

A prescriptive seed mix was designed for quick germination and growth, but also to facilitate establishment of a sustainable vegetative cover through the hot summer conditions and over the following winter and beyond. Key species included:

Festuca arundinacea var. K31– Tall Fescue – cool season turf forming grass
Eragrostis curvula –Weeping Lovegrass – warm season bunch grass
Cynodon dactylon var. Numex Sahara – Bermuda grass – warm season sod forming grass
Paspalum notatum – Pensacola Bahiagrass – warm season sod forming grass
Lespedeza cuneata – Serecia Lespedeza – Nitrogen fixing legume
Trifolium repens var. Durana – White Clover – Nitrogen fixing legume
Trifolium incarnatum var. Dixie – Crimson Clover - Nitrogen fixing legume

Lolium multiflorum – Annual Ryegrass – cool season annual used as a cover crop
Urochloa sp. – Browntop Millet – warm season annual grain used as a cover crop

Soil amendments included a micronized lime to quickly raise soil pH, 19-19-19 fertilizer with both a fast acting and a sustained release biostimulant. The seed and amendments were applied in the first pass with the BST. The flatter areas were then straw mulched at 4,480 kg/ha (4,000 lb/acre) and then covered with a hydraulically-applied mulch tackifier at 560 kg/ha (500 lb/ac) designed to hold straw and hay mulches in place. The slopes were designed with gradients of up to 3H:1V and an Engineered Fiber Matrix (EFM) was applied at 3,940 kg/ha (3,500 lb/ac) over the BST for additional erosion protection.

Figure 3 – Application of BST on level areas

Figure 4 – Cat tracked slope treated with BST

Wet conditions prevailed soon after the installations and over the month of April with the site receiving nearly 356 mm (14 inches) of precipitation. Despite the heavy rainfall amounts minimal erosion was observed. Some of the flatter areas were topped with an exposed very light colored, material known locally as "Ghost Clay", which led to some ponding and overland flow down over the 3H:1V slope. Degradable erosion control blankets were installed with additional seed in two areas where concentrated flow had caused some spot erosion. Meanwhile rapid and dense vegetative growth flourished within 5 weeks as highlighted in Figures 5 and 6.

Figure 5 – Growth over "Ghost Clay" on flat areas

Figure 6 – Luxuriant growth on 3H:1V slope

Over the succeeding weeks the vegetative cover was fully restored and ADEM granted the site owner a Notice of Termination on May 27, 2015. Site visits in the spring of 2016 and summer of 2017 have revealed the vegetative cover remains sustainable and intact while the OM content has more than doubled from ≤1% to over 2.2%. As designed, the species composition has changed from the rapidly growing cool season annuals and tall fescue to a cover now dominated by the more locally adapted warm season perennial species – Bermuda grass, weeping lovegrass, lespedeza and clovers that will persist better through the hot summer conditions. Further, the amount of biomass has dramatically increased with successional tree and shrub species beginning to establish in areas that have not been mowed. This would suggest that a significant amount of OM is being held within active plant tissue in addition to the OM increase observed in the underlying soil.

Case Study #2 – SCDOT Cypress Gardens Road:

The South Carolina Department of Transportation (SCDOT) requires projects to be stabilized with vegetative cover prior to completion. SCDOT has developed specifications for seeding and for erosion control products to facilitate growth of vegetation that provides immediate erosion control as well as sustainable, long-term erosion prevention. Unfortunately, SCDOT frequently encounters soils with little to no topsoil with very low OM levels (< 1%) – typically considered deficient and detrimental to plant growth.

To address poor soils low in OM, SCDOT developed specifications for two types of organic amendments: Compost and Hydraulic Biotic Soil Amendments (HBSAs), which are BSTs. Compost is defined as a product resulting from the controlled biological decomposition of organic material under aerobic conditions and must be US Composting Council Seal of Testing Assurance certified. Compost is typically applied pneumatically and provides some erosion prevention on mild slopes. HBSAs are engineered organic amendments that consist of OM and nutrient sources combined with soil building and biostimulant components. HBSAs are typically hydraulically applied using hydroseeding equipment and may include erosion control properties (1-step application HBSA) or require a separate erosion control product installed over the HBSA (2-step application HBSA).

In 2014, SCDOT performed an emergency bridge repair on Cypress Gardens Road in Moncks Corner, South Carolina. The additional bridge clearance resulted in building steep fill slopes to the height of the new bridge. The total area of slopes was approximately 0.8 hectares (1.9 acres) with an average slope of 2H:1V and some steeper areas. SCDOT performed seeding per specifications three separate times in 2014 and 2015, each time performing a standard soil test and addressing soil pH with lime application and addressing nutrient requirements with fertilizer per the soil test results. While the results of the standard required soil test showed the soil was capable of sustaining vegetation, SCDOT was unable to achieve permanent vegetation, leading to severe rill erosion of the steep slopes. It was noted at this point in time that the standard soil test did not require or include an OM test. An additional soil test was conducted on December 16, 2015 that included an OM test and the results indicated the soil contained only 0.7% OM. SCDOT considered hauling in topsoil to relieve the OM deficiency. However with the typical SCDOT topsoil cost of $52/ cubic meter ($40/ cubic yard), the estimated cost of the topsoil alone would have been over $30,000. The estimated cost of using HBSA for this project including seed, fertilizer and other amendments was $23,000. The multiple unsuccessful seeding attempts, slope erosion, low on-site soil OM and high topsoil cost made Cypress Gardens Road a prime candidate for demonstrating the benefits of using organic soil amendments.

Table 2 – Soil Sample Results

Soil Test Parameter 12/16/2015	Results	Comments
Organic Matter	0.7%	Deficient
Soil pH	7.1	OK
Buffer pH	7.85	OK
Phosphorus (P)	27 kg/ha (24 lb/ac)	Low
Potassium (K)	48 kg/ha (43 lb/ac)	Low
Calcium (Ca)	1,347 kg/ha (1,203 lb/ac)	Sufficient
Magnesium (Mg)	57 kg/ha (51 lb/ac)	Medium
Zinc (Z)	0.8 kg/ha (0.7 lb/ac)	Low
Manganese (Mn)	6 kg/ha (5 lb/ac)	Low
Boron (B)	0.2 kg/ha (0.2 lb/ac)	Sufficient
Copper (Cu)	0.6 kg/ha (0.5 lb/ac)	
Sodium (Na)	17 kg/ha (15 lb/ac)	
Cation Exchange Capacity (CEC)	4.5 [meq/100g]	
Nitrogen Recommendation	134 kg/ha (120 lb/ac)	
Phosphorus Recommendation	112 kg/ha (100 lb/ac)	
Potassium Recommendation	134 kg/ha (120 lb/ac)	
Lime Recommendation	No Lime Required	

The site was divided into five separate plots to demonstrate three different organic amendment treatments: one 0.07 hectare (0.17 acre) compost plot, two 1-step HBSA plots totaling 0.36 hectare (0.9 acre), and two 2-step HBSA plots totaling 0.34 hectare (0.83 acre). The compost plot had an average slope of 3H:1V and the HBSA plots had an average slope of 2H:1V or steeper. Soil amendment product applications, along with seeding applications following the SCDOT specifications, occurred on January 21, 2016. The compost and 1-step HBSA plots were seeded at the same time, as they were located on the same side of the road. The 2-step HBSA plots were located on the other side of the road and seeded later in the day, after the necessary lane closure was reversed, so seeding rates varied slightly. The type of slow release organic fertilizer that was used varied slightly based on availability on-site at the time of application. Regular site visits were performed every 2 to 4 weeks for the following 18 months.

Table 3 – Compost Application: Total Area 0.07 ha (0.17 ac)

Item	Application Rate
Bermuda grass	77 kg/ha (69 lb/ac)
Rye Grain	116 kg/ha (104 lb/ac)
Crimson Clover	27 kg/ha (24 lb/ac)
Dutch Clover	6.3 kg/ha (5.6 lb/ac)
Weeping Lovegrass	6.3 kg/ha (5.6 lb/ac)
Compost	378 m^3/ha (200 yd^3/ac), 3-5 cm (1-2 in) layer

Table 4 – One-Step HBSA Application: Total Area 0.36 ha (0.90 ac)

Item	Application Rate
Bermuda grass	77 kg/ha (69 lb/ac)
Rye Grain	116 kg/ha (104 lb/ac)
Crimson Clover	27 kg/ha (24 lb/ac)
Dutch Clover	6.3 kg/ha (5.6 lb/ac)
Weeping Lovegrass	6.3 kg/ha (5.6 lb/ac)
Fertilizer 4-4-4	3,733 kg/ha (3,333 lb/ac)
1-Step HBSA	5,973 kg/ha (5,333 lb/ac)

Table 5 – Two-Step HBSA Application: Total Area 0.34 ha (0.83 ac)

Item	Application Rate
Bermuda grass	66 kg/ha (59 lb/ac)
Rye Grain	100 kg/ha (89 lb/ac)
Crimson Clover	23 kg/ha (21 lb/ac)
Dutch Clover	5.4 kg/ha (4.8 lb/ac)
Weeping Lovegrass	5.4 kg/ha (4.8 lb/ac)
Fertilizer 6-3-0	3,374 kg/ha (3,012 lb/ac)
2-Step HBSA	6,072 kg/ha (5,422 lb/ac)
Flexible Growth Medium (FGM)	1,147 kg/ha (1,024 lb/ac)

Organic amendments helped establish vegetation and prevent erosion on a site where traditional seeding practices were repeatedly not successful and topsoil was not a feasible solution. Minor rill erosion was observed on the compost plot shortly after the application prior to the establishment of vegetation. Erosion was not observed on the HBSA plots prior to the establishment of vegetation. On all plots, the nurse crop (Rye Grain) emerged in early February and provided a sufficient stand of temporary cover through March and April. This demonstrated that soil amendments are capable of providing rapid growth of temporary cover species even during difficult periods of the growing season.

In May as the temperatures increased, the cool season nurse crop gave way to the permanent species in the seed mixture (Bermuda grass and Weeping Lovegrass) as well as volunteer grass and weed species. The HBSA plots achieved a sufficient stand of permanent vegetation (a uniform perennial vegetative cover with a density of 70% of each square yard of the seeded area) by late July. The compost plot took slightly longer, achieving a sufficient stand of permanent vegetation by late September. This transition period from temporary cover to permanent cover took longer than anticipated because the dense temporary cover inhibited the establishment of the permanent cover. This observation indicated that when using soil amendments, temporary nurse crop seeding rates may need to be reduced to ensure permanent vegetation establishment is not slowed or choked out.

On October 8, 2016, Hurricane Matthew resulted in a 100-year rainfall event with over 250 mm (10 in) of rain in 24 hours and no erosion or damage to slopes was observed afterwards. Time-lapse photographs of the first 12 months of growth are shown for the compost plot (Figure 7), the 1-step HBSA plots (Figure 8), and the 2-step HBSA plots (Figure 9). These photos show that a variety of different plant species grew and stabilized the slopes in the compost and HBSA applications.

Figure 7 – Photographs of compost demonstration plot, clockwise from top left: January 2016, April 2016, September 2016, and January 2017.

Figure 8 – Photographs of 1-Step HBSA demonstration plot, clockwise from top left: January 2016, April 2016, September 2016, and January 2017.

Figure 9 – Photographs of 2-Step HBSA demonstration plot, clockwise from top left: January 2016, April 2016, August 2016, and December 2016.

On June 19, 2017, follow up soil tests and organic matter tests were performed for each specific plot. The organic test results ranged between 1.3% and 1.9% OM, showing an increase in OM from the soil test conducted in December of 2015 for all of the plots.

Table 6 – Follow up Soil Sample Results

Soil Test Parameter 6/19/2017	**Compost** 3H:1V Avg. Slope	**1 Step HBSA Avg.** 2H:1V Avg. Slope	**2 Step HBSA Avg.** 2H:1V Avg. Slope
Organic Matter	1.8%	1.4%	1.8%
% Increase OM	157%	100%	157%
Soil pH	7.7	7.9	7.6
Buffer pH	7.95	7.93	7.88
Phosphorus (P)	1.1 kg/ha (1.0 lb/ac)	8.4 kg/ha (7.5 lb/ac)	15 kg/ha (13 lb/ac)
Potassium (K)	69 kg/ha (62 lb/ac)	64 kg/ha (57 lb/ac)	71 kg/ha (63 lb/ac)
Calcium (Ca)	13,868 kg/ha (12,382	13,157 kg/ha (11,747	6,444 kg/ha (5,754
Magnesium (Mg)	197 kg/ha (176 lb/ac)	174 kg/ha (155 lb/ac)	99 kg/ha (88 lb/ac)
Zinc (Z)	0.33 kg/ha (0.30 lb/ac)	1.2 kg/ha (1.1 lb/ac)	1.4 kg/ha (1.3 lb/ac)
Manganese (Mn)	12 kg/ha (11 lb/ac)	16 kg/ha (14 lb/ac)	6.7 kg/ha (6.0 lb/ac)
Boron (B)	0.33 kg/ha (0.30 lb/ac)	0.50 kg/ha (0.45 lb/ac)	0.39 kg/ha (0.35 lb/ac)
Copper (Cu)	0 kg/ha (0 lb/ac)	0.11 kg/ha (0.10 lb/ac)	0.45 kg/ha (0.4 lb/ac)
Sodium (Na)	18 kg/ha (16 lb/ac)	17 kg/ha (16 lb/ac)	13 kg/ha (12 lb/ac)
CEC	32.2 [meq/100g]	30.7 [meq/100g]	15.9 [meq/100g]

Conclusion:

Biotic Soil Technology is an emerging field of manufactured growth media containing naturally derived, recycled biodegradable fibers, biostimulants, biological inoculants, soil building components and other materials designed to accelerate sustainable vegetative establishment and promote regeneration of denuded soils.

Two case studies document protocols for pre-installation testing, inspection during installation, and post-installation monitoring and inspection while demonstrating the proven effectiveness of biotic soil technology in distinct situations where pre-existing soil organic matter and fertility were minimal. In each case the owners monitored and documented excellent results with significant savings over traditional topsoil and compost methods to increase organic matter content. In essence, soils were built in place versus the exorbitant costs associated with procuring, transporting and spreading imported materials. Both sites demonstrated rapid, complete and sustainable vegetative establishment with minimal erosion and significant increases in organic matter over the reported monitoring periods.

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