



The Blade

Monthly Newsletter of the
Grey Wooded Forage Association

November 2019



GETTING THE DIRT ON SOIL HEALTH
Winfield, October 22

SAVE THE DATES!

DATE	EVENT	LOCATION
Dec. 10-12	Western Canadian Conference on Soil Health and Grazing—SOLD OUT	Double-Tree Hotel West Edmonton
Jan. 18	Ladies' Livestock Lessons	Cremona—Poster on Page 4
Jan. 28	Weed and Pasture Management Workshop	Ponoka—Details to be announced
Feb. 3-5	Soil Health Workshop with Kris Nichols	Leduc—Details TBA
Feb. 13	Ranching Opportunities	Olds College—Poster on Page 10
Feb. 26	Environmental Farm Plan workshop	Lacombe County—Details TBA

Grey Wooded Forage Association

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to our digital mailing list
Published by: Brenda Kossowan
Cover: Producers learn sampling skills at a
soil clinic in Winfield with
Kris Nichols and Kim Cornish
(Brenda Kossowan photo)

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and Extension Council of Alberta

Office Report

By Brenda Kossowan, business manager

We're now smack in the midst of that time of year when the farming and ranching community is engaged in learning new stuff—or setting up opportunities for spreading the word about stuff we've learned.

As our Ag Field Specialist states in his article, we're ramping up our extension and applied research activities, with considerable emphasis in bringing new ideas to livestock and forage producers.

During our annual workshop in spring, we offered a glimpse of the possibilities available for using drones in managing your fields and your animals. From counting cows and seeking missing animals in the bush to measuring the volume of a silage pile, Markus Weber from LandView drones exposed fascinating insight into the ways an eye in the sky can improve management on the ground.

Picking up on that seminar, we joined with Markus and his crew to put on a two-day drone school early in November—the first time LandView had tailored its agricultural course to livestock production. Participants got some intense training in Canada's new regulations and drone safety, then trooped outside for some basic flight training. There were extra brownie points from the instructors for those who could fly backwards or keep the drone facing inward while flying in a circle. Nobody crashed.

Markus and his team gave additional instruction in the applications they have found most useful for graziers and forage producers.

The caveat to farmers, said instructor John Church, BC Regional Innovation Chair in Cattle Industry Sustainability at Thompson Rivers University, is that you can use drones to manage your herd or to monitor the cattle, but it's pretty difficult to cross those boundaries once they've been set. Cattle that have become used to drones flying overhead will not move away from them, while those that have been herded by drones will not stand still and be counted when the mechanical bird appears.

While a number of the participants used the last 90 minutes of the course to write the test for their basic drone pilot licenses, others devoted the time to learning how to set up a scan over a specified field. Overhead scans, which stitch hundreds of images into a single image, can be used to find weeds, investigate soil health, evaluate the layout of a yard and a plethora of other practical applications.

GWFA will certainly look at using drones in future projects, with both staff licensed to fly and keen to learn more ways to assist our community in this technology.

With organization of the Western Canadian Conference on Grazing and Soil Health down to the brass tacks, members of the Red-Bow Agricultural Partnership are turning their sites to the 2020 editions of Ladies Livestock Lessons and Ranching Opportunities.

Red-Bow was formed about 15 years ago by a consortium of counties in the South Central area of the province, along with Olds



College; Cows and Fish; Foothills Forage and Grazing, and GWFA. County members include Clearwater, Red Deer, Mountain View, Rocky View, Kneehill, Wheatland and the Municipal District of Big Horn.

Ladies Livestock Lessons, set for the Mountain View Heritage Centre near Cremona on January 18, will bring discussions of animal health, pasture management, pain medication for livestock, grazing management for species at risk, animal nutrition and mental health. The day will be capped with an all-female producer panel and a culinary demonstration with samples to taste. Ranching Opportunities runs at Olds College on February 13. The agenda includes two sessions—one plenary and one breakout—with Jim Gerrish, a livestock handling demonstration with Dylan Biggs, Markus Weber's drone presentation and a lively discussion on large-animal rescue with Rebecca Husted from Georgia-based Technical Large Animal Emergency Rescue. Kim Cornish will talk about measuring and mapping soil carbon and there will be a producer panel on using watering systems as a tool for grazing management.

In closing, you will notice that this month's edition of the Blade includes an overview of recently-published research on how biochar reacts in clay soils. The two-page article is excerpted from a scientific journal published online by a Swiss institute, MDPI (Multidisciplinary Digital Publishing Institute). This is an open peer reviewed publication, meaning it does not adhere to the strict rules of other scientific journals. However, the research performed by scientists in Sydney and Beijing does raise some discussion in our quest for better understanding of soil carbon, which could form a basis for applied research in soil amendment and animal health. Next month, watch for an article on management tactics to improve soil structure and microbial activity.

Is your annual compensation review coming this year?

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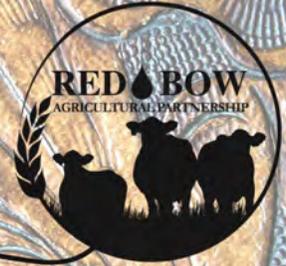
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Registration Deadline: January 14th, 2020



Topics include: Breaking Barriers in Ag: Mental Health on the Ranch, Animal Health: Preventative Medicine & Pain Management, Canadian Beef Centre of Excellence: Culinary Demonstration & Tasting, Female Producer Panel – Highlighting Stewardship & Best Management in Agriculture, Species At Risk & Grazing Management, Livestock Nutrition & Alternative Feeds, Online Tools & Agriculture Apps, Grazing Management 101 for Small Holdings (topics subject to change).

For more information, registration details & current agenda visit www.redbowag.com or contact Daniela Archur at Mountain View County Agricultural Services
Ph: 403-335-3311 Ext 204 Email: darcher@mvcountry.com

GWFA Gits 'er Done

By Greg Paranich, Agricultural Field Specialist

The Grey Wooded Forage Association has reamped up its activities in 2019. After a brief period of restructuring, we moved forward with several field projects and workshops.

Not unlike the rest of agriculture, the wet summer was a challenge to get things done on time or done at all. The following is an overview of our activities in 2019 and a summary of plans for the coming year.

PROJECTS

Syngenta Pollinator was a continuation of coordinating seed mixes from Syngenta to the ongoing cooperators to continue to establish and grow pollinator friendly plots. The plots were verified and documented for level of establishment.

Stem Mining Weevils in Canada Thistle

Weevil plot evaluations and larvae counts were conducted in July on the Medicine River sites (2), as well as the established Sundre and Mountain View County (office) locations. We did a follow up in August to document thistle damage evidence. The collected data on Weevil information is being consolidated for presentations this winter.

Hardy Alfalfa continued into its sixth year with Darren Bruhjell and Lacombe Research and Development Centre staff collecting plot data this summer to be shared with Grey Wooded Forage Association through in-house media and seminars.

Soil Health Benchmark Sampling is a Province wide collaboration between Grey Wooded Forage Association and several other Associations in Alberta in a four-year soil health project. Based out of the Chinook Applied Research Association soil lab in Oyen, soil parameters are measured from various soil types and managements to establish a baseline of data for future comparisons.

Sustainable Annual Forages Intercropped with Cereal Silage plots were seeded to variable rate barley strips June 6 and cross seeded with four blends of alternative forage mixtures on June 10. On June 17, we “planted” two pairs of cotton underpants for the “Soil Your Undies” challenge, to be unearthed as part of our follow up soil workshop in the fall. Recent rains will support good emergence and a planned “establishment tailgate” session in July. We will compile relative yield and feed nutrition data collected on the plots with Clearwater County for use in a 2020 winter workshop on Cover Crops.

Annual Forages & Cover Crops to examine uses of annual forages in feed strategies (green feed/silage/swath grazing) and the use of cover crops for feed and soil health benefits. Examine traditional use of cereals, new winter annuals potential, corn, and silage BMP's. New annual cover crops implementation.

ADVISORY SERVICES

We continue to do customer consultations via phone, to help producers find some solutions to questions they may have regarding forage, livestock, or soil management.

Pasture Walks are positioned as membership benefits only. A half-day review and pasture walk will evaluate situations and find solutions and recommendations.

ENVIRONMENTAL ACTIVITIES

ALUS (Alternative Land Use Services) provides financial incentives towards management that protects and enhances wetlands and riparian areas on Canadian farms. The GWFA currently sits on the Producer Advisory Committee for the Red Deer County ALUS



group and supports ALUS activities in Mountain View and Lacombe Counties.

Environmental Farm Plans serve as valuable planning tools for producers committed to environmental stewardship. GWFA assists in the delivery of EFP workshops with various counties. I am working toward certification as an EFP Technician, which will enable us to lead future workshops and provide technical assistance directly to producers.

WORKSHOPS AND FIELD DAYS

Education Agriculture Tour, put on by Clearwater County on May 15, saw 125 Grade Four students tour four Rocky Mountain House-area farms and ranches to learn about various aspects of agriculture. GWFA teamed up with Devin Knopp from Benalto Ag Services and Leslieville-area grazer John Reid to deliver interactive presentations on forage, crops, and soils at Bob Aasman's Arena, north of Rocky Mountain House.

Annual Spring Workshop and AGM held June 13/19 at Westerner Park in conjunction with the AGM events, had very good feedback and reviews from more than 30 participants.

Managing Livestock with Drones was a very popular session with participants wanting to explore this technology further. Discussions with LandView (Marcus Weber) are in progress to explore the possibility of a Drone School (2 days) for those interested in getting the training and certification for drone operations, at minimal cost to GWFA, probably in the fall.

Innovative Power Fencing had both sessions full of a lot of interaction and questions on power fence trouble shooting and solutions. In addition, Brenden Anderson shared his successful fencing experiences with the crowd. Lone Star Ranch Supplies (Steve Cannon) is looking forward to partnering with GWFA on a potential in-field power fencing demonstrations ranging from introductory power fencing basics for beginners to new technologies for advanced users. We are investigating how best to deliver this event.

Feed Analysis: Myth vs Facts was a presentation of helpful information covering proper sampling techniques to sample interpretation and how to make the most of your analysis information. Nutritional needs for various classes of livestock were also addressed. Biochar research (Lee Eddy) was also touched on as an emerging technical tool for livestock and forage production. Blue Rock Animal Nutrition (Kristen Ritsen-Bennett & Lee Eddy) expressed interest in another partnered session/demonstration in late summer or fall regarding feed sampling and animal nutrition management for fall/winter rations.

Understanding Hybrid Vigor in Cattle, although not heavily attended, had very keen interest in those who did take in this session. The commercial availability and application of this technology was presented and could benefit by being part of a larger agenda in the future. Alberta Agriculture (Andrea Hanson) is willing to contribute this, and other livestock management presentations in our future KTT events.

AGM Dinner program had two presentors including Christine Campbell from ALUS informing attendees on their program opportunities for farmers and ranchers. Kim Nielsen of 4 Clover Ranch near Rocky Mountain House shared his experiences of grazing cattle in Canada and Australia.

Gittin' er done — GWFA updated continued from previous page

Get the Dirt on Soil (health and carbon) workshops with Kris Nichols and Kim Cornish. GWFA aided in hosting four workshops, in partnership with Red Deer County at the Cottonwood Hall on June 18, Lacombe and Ponoka Counties at the Lincoln Hall on June 19, Wetaskiwin County at Winfield on October 22 and with Mountain View County at their headquarters on October 24. The seminars were well reviewed by attendees who found them informative.

Rancher's Drone School was held at Lincoln Hall, in partnership with Land View Drones and Lone Star Ranch & Sales, was held pm November 4-5 at Lincoln Hall, offering livestock producers information on how to incorporate drones into their management systems. Participants received flight training, basic drone ground schooling and an opportunity to take the Transport Canada exam and obtain a Basic Pilot's Certificate for legal drone operations. A spring session is being considered, if interest warrants.

AG SMART

West Country Ag Tour (August 20) featured several great Ag sites including the Annual Forage plots with cover crops and barley silage combinations. Growing interest in cover crop opportunities will be followed with more emphasis in future sessions.

Annual Forage/Cover Crop Tailgate Plot Walk held on July 25 at the plot site just outside of Rocky Mountain House. The morning session had seven attending with an extended discussion period reflecting a high level of interest in adopting cover crops into their operations. The evening session was cancelled due to an outbreak of long-awaited haying conditions. This was great way to exchange ideas, opinions and information.

IN THE WORKS

Red-Bow Agricultural Partnership events that GWFA helps organize and support include Ladies Livestock Lessons and Ranching Opportunities. Please see the Coming Events section and posters in this newsletter.

Pasture and Weed Management meeting partnered with AFSC/GWFA/Ponoka County will be held in Ponoka (Calnash Ag Event Centre) January 28, 2020. Agenda will include AFSC forage/pasture insurance products, County range weed concerns, Grazing for Weed Management, and possibly Range and Pasture weed control products (Corteva).

Greener Pastures Ranching with Steve Kenyon, presenting regenerative agriculture and intensive grazing, set for February 24 and 25 at a locations to be announced.

Growing Corn and Cover Crop Basics Workshops are in planning stages, potentially in mid to late February and early March at locations to be announced.

Guide to Growing Forage Corn: Work has started on a GWFA guide booklet and power point presentation featuring basics for corn growers on selection; planting and establishment; weed control; plant stages to recognize; harvest and feed evaluations; best management practices for silage, and winter grazing BMPs.

Spring Workshop, Banquet and Annual General Meeting is set for June 11, 2020 at Westerner Park, Red Deer. Mark the date as this will be another outstanding day of presentations, demonstrations and a live auction to help raise operating funds.

GWFA strives to provide relevant information that is of value producers in forage, livestock and soil management. Please let us know of any topics that would be of interest to you.



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Block, tub, mineral or supplement?

Article provided by the Alberta Ag-Info Centre

What should producers consider when choosing combinations of feeds and supplements that provide a balanced ration this winter?

Barry Yaremco, beef and forage specialist at the Alberta Ag-Info Centre, says there are many questions to answer when looking at lick tubs, molasses blocks, mineral products and protein supplements.

“Are the products the best choice for the type of animal being fed and the feeds that are part of the program? Is the product a cost-effective method to supply additional nutrients to a feeding program? Do these products have the capacity to supply the required nutrients?”

Before answering those questions, he says producers need to have feed test results for the feeds that are going to be used to have a starting point for balancing rations, the weights of the animals being fed and the total supply of each feed; knowing the number of bales and weight, for example.

“Without taking into account these factors, any attempt to provide a balanced ration can create issues. If the quality of the feed is not known, there is no way to know if the tub, block, mineral or supplement is needed. If there is no defined starting point to the process, it is difficult to know if the actions are helping or hurting the situation.”

He says it is understandable that farm and ranch owners or managers are trying to maximize the number of healthy calves born this year. They also require a high reproductive efficiency for the upcoming breeding season.

“This is sound management, and it is well understood that nutrition has a big part to play in calving and re-breeding success. Good management also involves achieving the objectives as efficiently as possible, including minimizing the costs when feeding and supplementing cows.

“Harlan Hughes, a beef economist in North Dakota, stated in the mid-1990s that reducing winter feeding costs by \$1 increases overall profitability of the operation by \$2.48.”

Supplementation programs typically supply energy, protein, minerals, vitamins or a combination of the four. Producers need to check if the product of choice or a combination of products meets their requirements.

“In this example,” says Yaremco, “we will assume that the ration is short of protein and one pound of a 20-per-cent protein block (\$385 per tonne or 17.5 cents per pound) is required. How does this cost compare to adding wheat distillers grains with solubles (WDG) that contains 48-per-cent protein at a cost of 10 cents per lb. To provide the same amount of protein, the distiller should be fed at 0.4 pounds at a cost of four cents per head per day. The WDG needs to be fed with grain or pellets. The cost of processing and delivering the grain needs to be calculated into the total cost. With the grain and distiller’s feeding plan, it is relatively safe to assume that every animal will receive some grain or protein every feeding. When feeding tubs, blocks, supplements or mineral free choice, there is no way to know how much product an animal is consuming and at what interval. The free choice system has the greatest risk of not achieving the intake that is needed.”

He adds that, in this example, a 1400-pound cow in late pregnancy requires a nine-per-cent protein diet (dry basis) or roughly 1,020 grams of protein per day.

“Adding one pound of a 20-per-cent block or supplement increases protein content in the ration by 90 grams. The protein content of the diet increases by 0.5 per cent on a dry matter basis. If the supplied ration is at eight per cent, adding one pound of a 20-per-cent product

improves the situation, but it does not meet requirements. Without feed test results, the ration could easily be 12 per cent protein and there is a protein supplementation cost of 17 cents a day per cow that is not required. This is hard-earned money that does not need to be spent.”

When feeding cereal silage, greenfeed or swath grazing to pregnant cows, Yaremco says a lack of calcium and magnesium is the biggest issue.

“In this situation, an added product should have more calcium (Ca) than phosphorus (P). Most block and tub products along with some minerals have equal amounts of Ca and P (1:1 ratio) or twice as much calcium compared to phosphorus, a 2:1 Ca to P ratio. In many situations, the Ca to P ration in a mineral product may need to be 8:1 or higher, similar to a feedlot type mineral, to bring Ca and P levels into line.”

He notes that tub or block products have lower Ca and P levels compared to a dry mineral, and it is difficult to keep minerals in suspension during the manufacturing process.

“To successfully register a feed product, the Canadian Food Inspection Agency requires that the nutrient content in the first block must be the same as what is found in the last block in a batch. Ca and P are difficult to keep in solution during the mixing and manufacturing phase, so there could be a lower concentration in the final product. It is generally more efficient and more economical to feed a dry mineral to provide Ca or P in a ration rather than using a tub or block.”

“Let’s look at a swath grazing situation where the feed contains 0.32 per cent Ca and 0.2 per cent P and the Ca content in the tub or block is 4.7 per cent Ca and 1.75 per cent P. The final feeding program would require 3.9 pounds of the block product to achieve a 2:1 Ca to P ratio. Cost would be \$0.63 per head per day, when the block costs 17.5 cents a pound.”

He notes that other nutritional problems could occur with this feeding program, as some nutrients would be excessive, causing a reduction in performance-

“However, a second option would be to feed 0.067 of a pound (30 g), of limestone (38 per cent Ca) to achieve the 2:1 ratio. The cost would be one to two cents per head per day. If a feedlot type mineral with 24 per cent Ca and eight per cent P is fed at 0.25 lb. a day, the cost would be roughly eight cents per head per day. The key is to minimize expense but provide a proper ration.”

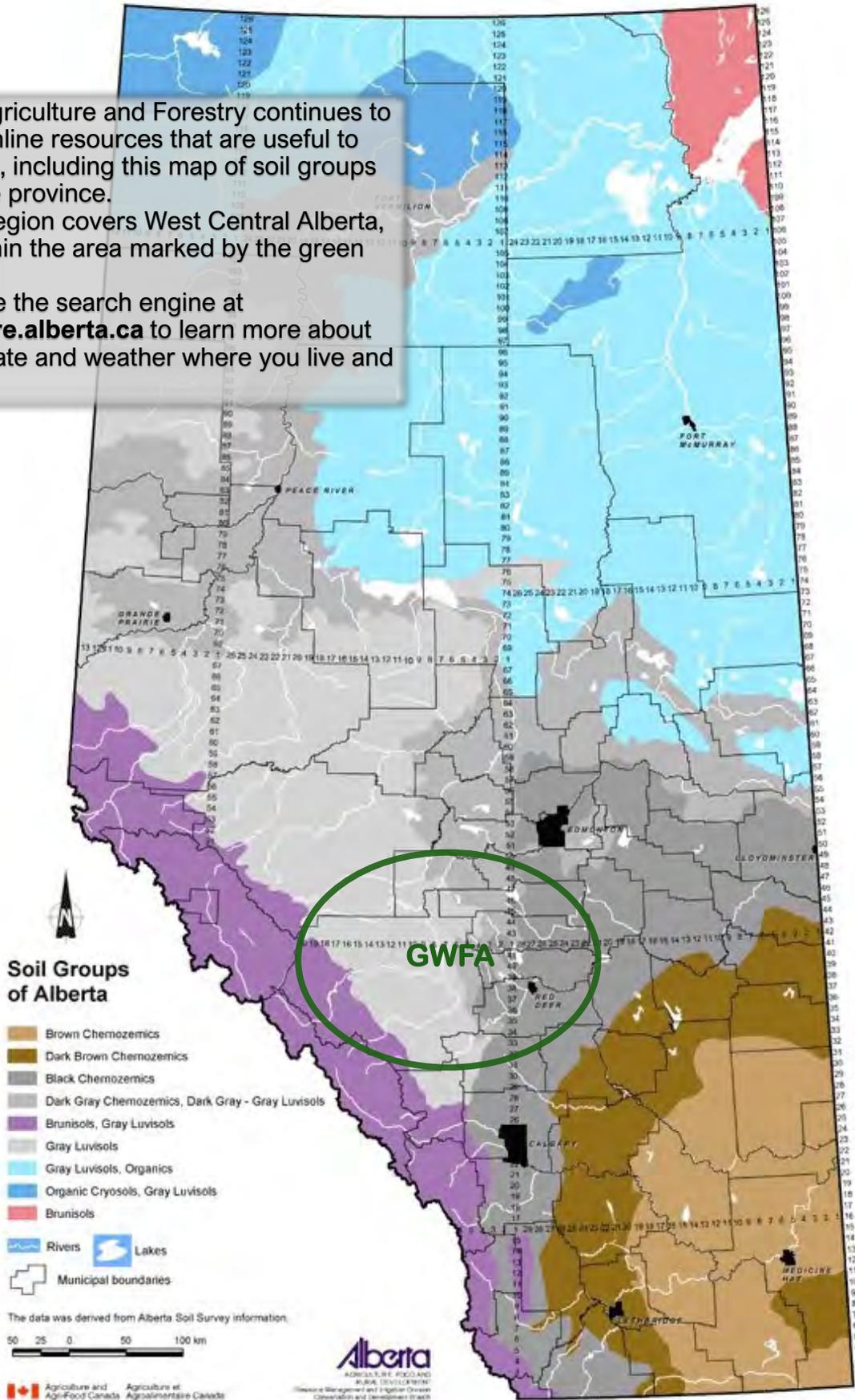
Limestone provides only calcium, whereas the feedlot mineral will also have other minerals and trace minerals along with vitamins. Using a mixed commercial product that provides more than one nutrient may be more efficient than trying to blend products at home.

Yaremco says every farm or ranch is different and there are many possible feed combinations to provide a balanced ration.

“Adopting a feeding practice must fit your management style and operation. If necessary, consult with a nutritionist to balance the ration, or use a ration-balancing program such as CowBytes to do the work yourself.”



Alberta Agriculture and Forestry continues to provide online resources that are useful to producers, including this map of soil groups across the province. GWFA's region covers West Central Alberta, falling within the area marked by the green oval. Please use the search engine at agriculture.alberta.ca to learn more about soils, climate and weather where you live and farm



Evaluation of the Influence of Individual Clay Minerals on Biochar Carbon Mineralization in Soils

By Qingzhong Zhang, Chinese Academy of Agricultural Sciences, Beijing with Claudia Keitel and Balwant Singh of The University of Sydney, NSW, Australia

Editor's note: The following article is excerpted from a research paper published on December 3, 2019, by MDPI in Basel, Switzerland. This copy has been edited for clarity and brevity. The full paper is available online at mdpi.com. This is an open access article distributed under the terms and conditions of Creative Commons Attribution. Visit creativecommons.org/licenses/by/4.0 for details.

INTRODUCTION

In recent years many studies have been conducted on biochar application to the soil to evaluate its potential multiple benefits, not only for increasing soil carbon storage, and therefore mitigating climate change, but also improving soil quality, and promoting and sustaining crop production. Woolf *et al* modelled that biochar has the potential to substantially reduce greenhouse gas emissions, in the order of 1.8 petagrams of CO₂-C per year. This potential is, however, largely dependent on the stability of biochar-C in the soil. There is ample evidence from several incubation studies and historical field samplings that biochar can persist in soils for a long time, with estimated mean residence time generally well over 100 years. The persistence of biochar in soils depends on several factors including the pyrolysis temperature of biochar, biochar feedstock, environmental conditions and soil properties. Several researchers have evaluated biochar mineralization in soils, particularly in relation to the influence of biochar addition on the stability of native soil organic carbon (SOC), referred to as “priming”. Positive, negative and neutral priming effects of biochar have been reported on the mineralization of native SOC.

ABSTRACT

Clay minerals have a major role in the stabilization of natural organic matter in soils. Chemical interactions of soluble organic compounds with mineral surfaces, and incorporation of soil organic matter into soil aggregates are the main mechanisms for the preservation of organic matter in soils. Similarly, the stabilization of biochar-C has been postulated to be based on the association of significant amounts of biochar-C with mineral fractions or microaggregates in soils.

There is some evidence that clay minerals in soils decrease the mineralization of biochar-C; for example, the mineralization of barley root biochar-C decreased with increasing clay content in three Danish soils. Nevertheless, there is limited research on the role of specific clay minerals in the stabilization of biochar carbon. For example, Fang *et al* observed a substantially lower mineralization of biochar-C in an Oxisol, where iron and aluminium oxides dominated the clay fraction, compared to other soils that contained phyllosilicates in the clay fraction. Consequently, the mean residence time of the biochar was 22–35 percent longer in the Oxisol than in the other soils.

Similarly, the mineralization of a pine wood biochar was approximately half when incubated in an andesitic soil, which contained short-range order clay minerals, compared to a granitic soil. However, due to the co-existence of several minerals in soils in previous studies, it is difficult to isolate and quantify the role of individual clay minerals in the preservation of biochar-C.

We aimed to unravel the role of specific clay minerals in influencing the mineralization of biochar-C in soil. We hypothesized that clay minerals will have varying effects on biochar-C mineralization, depending on their charge characteristics, i.e. variable and permanent charge, and that the mineralization of

biochar-C will decrease with increasing specific surface area of the mineral.

To test our hypothesis, we measured the mineralization of biochar-C in artificial soils in the presence of three clay minerals, i.e., kaolinite, smectite and goethite, using an incubation experiment. Additionally, we measured the mineralization of native soil carbon to evaluate the effects of clay minerals and biochar on the stability of native soil carbon.

Although association between mineral and biochar carbon have been speculated in some studies, still there is no direct evidence for the influence of individual clay minerals on the mineralization of biochar carbon in soils.

To address this, we conducted an incubation study using monomineralic soils constituted by separately mixing pure minerals, i.e., smectite, kaolinite, and goethite, with a sandy soil. Switch grass biochar (400C) was added to the artificial soils and samples were incubated for 90 days at 20 C in the laboratory.

The CO₂-C mineralized from the control, and biochar amended soil was captured in NaOH traps and the proportion of C mineralized from biochar was determined using (delta C 13) isotopic analysis.

The clay minerals significantly decreased the cumulative total carbon mineralized during the incubation period, whereas biochar had no effect on this.

The least amount of total C was mineralized in the presence of goethite and biochar amended soil, where only 0.6 per cent of the native soil organic carbon (compared to 4.14 per cent in control) and 2.9 per cent of the biochar-C was mineralized during the 90 days incubation period. Native SOC mineralization was significantly reduced in the presence of biochar and the three minerals. Goethite was most effective in stabilizing both biochar and the native soil organic carbon. The short-term data from this study demonstrate that biochar application in iron-oxide rich soils may be an effective strategy to sequester biochar carbon, as well as to stabilize native soil carbon.

DISCUSSION

Effects of Clay Minerals on Native SOC and Biochar-C Mineralization

Clay minerals can influence the mineralization of both native SOC and biochar-C, and thus the total C mineralization in the soil. Soil organic matter may be physically protected from decomposer organisms or their extracellular enzymes in micropores formed by soil aggregates. Furthermore, chemical interaction of soil organic matter (SOM) via complexation reactions on surfaces of Fe and Al (hydr-) oxides and phyllosilicates can protect native SOC against microbial mineralization. Smectite with a relatively larger specific surface area exhibited a weaker capability in reducing SOC mineralization than goethite and kaolinite in the absence of biochar. This finding is consistent with Bruun *et al* who reported that smectite has weaker capability of reducing SOC mineralization than kaolinite. Goethite and kaolinite were equally effective in reducing the mineralization of native SOC. The interaction of native SOC

(continued on Page 11)

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For the current agenda and list of
speakers visit www.redbowag.com

**Grazing Management
with Jim Gerrish**

Managing Cattle with Drones
Marcus Webber, LandView Drones

Low Stress Cattle Handling
Dylan Biggs, TK Ranch

Producer Panel:
Using water as a tool for pasture management

**Large Animal Emergency
Response**
Dr. Rebecca Gimenez-Husted

Soil Carbon Quantification
*Kim Cornish, Food Water Wellness
Foundation*



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with variable charged minerals, i.e., goethite and kaolinite, involving ligand exchange reactions, may have caused a decrease in the mineralization of native SOC.

Mineralization of biochar-C was lowest in the presence of goethite, which is consistent with the involvement of ligand exchange reactions between biochar and goethite surfaces as postulated by Fang *et al.* The involvement of ligand exchange reactions in clay-organic matter interactions has been frequently suggested. Such reactions occur between carboxyl and phenolic groups of organic matter and hydroxyl groups on the surfaces of Fe and Al oxides and at the edges of kaolinite and other phyllosilicates.

Decreased mineralization of biochar-C in the S+B+Ka, compared with S+B treatment, suggest the involvement of ligand exchange reactions between biochar and kaolinite surfaces. However, these interactions are stronger on goethite surfaces than kaolinite surfaces, possibly due to greater specific surface area and a greater number of sites per unit surface area in goethite than kaolinite. Fernández-Ugalde *et al.* also observed metal oxides and oxyhydroxides, and vermiculite contribute to the stabilization of biochar-C and native SOC.

Effects of Biochar on Native SOC Mineralization

Total C mineralized in biochar amended treatments consisted of C mineralized from the native SOC and biochar-C. Variable and sometimes contrasting effects of biochar on the total soil C mineralization have been observed in the literature. Researchers have reported that biochar had no effect, increased or decreased total C mineralization from soil. Our results illustrate that the addition of 400C switch grass biochar had no effect on cumulative C mineralization in the absence of added clay mineral to the soil. However, variable effects were observed in the presence of clay minerals, with increased CO₂ evolution in the presence of smectite and kaolinite, and decreased mineralization in the presence of goethite.

The priming effect of biochar on native soil carbon depends on several factors, including the duration of incubation experiment, and biochar and soil characteristics. In our study, the presence of biochar significantly decreased the mineralization of native SOC both in the absence and presence of clay minerals. Our results are in contrast with Fang *et al.*, who observed a positive priming effect of biochar on native SOC in the same soil, an Inceptisol. The contrasting results might be due to different biochar used in the two studies. Fang *et al.* used biochars pyrolyzed from Eucalyptus woody biomass at 450C or 550C, whereas the biochar in this study was produced at lower

pyrolysis temperature (400C) from switch grass. The switchgrass biochar contained a lower proportion of C as stable polyaromatic C, and a lower proportion of total OC as BPCA-C than the biochars used by Fang *et al.*

The presence of a relatively large amount of labile carbon in the switchgrass biochar possibly served as a source of energy for soil microbes, and was used in preference to the native C, particularly during the short incubation time. This mechanism has been described as substrate switching.

Additionally, the applied biochar possibly had a stabilizing effect on the native SOC via soil aggregation, a mechanism suggested by Fang *et al.* Keith *et al.* observed a similar effect in an incubation study where biochar addition resulted in a net negative priming effect on the mineralization of added labile organic C.

Interactive Effects of Biochar and Clay Minerals on Native SOC

No significant interactive effect of biochar and minerals on native SOC mineralization was observed in this study, though the minerals exhibited different patterns in reducing native SOC mineralization with biochar addition. Generally, the effect of combined addition of biochar, and a mineral in reducing the cumulative amount of native SOC mineralized was less than the sum of individual effects of biochar and a mineral. The effect of biochar was a dominant factor in this regard; however, the results of this short-term incubation study should be verified with long-term experiments, preferably under field conditions

Mean Residence Time of Native SOC and Biochar-C

The Mean Residence Time estimated for native SOC in soil alone (S treatment) is rather short (9.5 years), indicating the relatively labile nature of the native SOC. Since the control soil was almost pure sand, the SOC was not associated with any clay minerals. Hence, the free native SOC would be expected to mineralize relatively fast after the addition of nutrient solutions and microbial culture used in the experiment. The stabilizing effect of biochar on the native SOC is obvious with a significant increase in the MRT of the native SOC in the presence of biochar. The MRT of biochar in our study (about 86.7 to 138.6 years) is consistent with the short-term incubation experiment and low temperature grass biochars.

CONCLUSION

The biochar used in our study showed a good potential to reduce the mineralization of native SOC in soils, added alone or in combination with each of the three common soil clay minerals. Our results illustrate that biochar addition is most beneficial in soils containing Fe oxides (rather than phyllosilicates), as (1) biochar addition stabilized native SOC, and (2) added biochar-C has the potential to be stable for long periods. For future experiments, biochar properties such as feedstock and pyrolysis temperature, as well as climatic conditions should be considered, particularly for long-term incubation experiments and under field conditions.

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