Reversing Soil Acidity:
Effect of high-density stocking rate on beet lime incorporation, soil compaction, steer gain economics, soil microbial activity, and soil physical properties

Progress Report

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Measurement of soil hydrogen ion (H^+) is a function expressed logarithmically as the negative H^+ ion concentration. As soil pH declines and becomes more acidic, crop growth and productivity are negatively impacted when unhydrated aluminum (Al $(OH)_4$ becomes disassociated from the hydroxyl group result in positively charged aluminum Al^{3+} that is toxic to plants. There are soils in North Dakota that were formed on parent material that is naturally slightly acidic. Nonetheless, soil pH decline is accelerated by acids produced in soil following repetitious application of most nitrogen fertilizers, nitrate leaching and plant cation uptake, which results in anion accumulation promoting increased acidity (Cihacek et al., 2021).

Approaches to reversing soil acidity conditions include applying lime (Calcium carbonate, $CaCO_3$) sourced as a byproduct from sugar beet processing (beet lime) or municipal water treatment facilities. Beet lime is being used for this investigation. In order for elements in the soil solution to react and buffer acidic conditions some form of incorporation is necessary. Minimal soil disturbance from no-till seeding practices may not be sufficient to adequately incorporate lime into the root zone. In addition to light discing, the effect of animal hoof action during grazing of cover crops, where lime has been applied, might possibly be a mechanism for lime incorporation.

Yearling Steer Cover Crop Grazing:

A multi-specie full-season cover crop was planted early June for August grazing with yearling steers as a component in a four-crop rotation (Cover Crop, Spring Wheat, Corn, and Sunflower). To ensure adequate hoof action, a high-density stocking rate was used in which 60 crossbred steers (A x RA x Lowline x SM) grazed the study area for 21days. The grazing area of 9.478 acres was subdivided into 11 segments equaling 0.861636 acre grazing areas. Polywire electric fence was used to restrict grazing within designated high-density stocking areas and the steers were rotated to the next cover crop segment every other day. Steer average weights were 979 and 1,007 lbs. years 1 and 2, respectively, and the pounds of beef per acre was 67,160 and 70,140 lbs. years 1 and 2, respectively. Yearling steer average daily gain was 1.50 lb/day/steer both years of the study.

Beet lime cost was $50/T plus $10/T for custom application. Lime treatments were 0, 2, and 4 T/ac. Total cost to apply 2 T/ac was $120 and the 4T/ac rate cost $240/T. Although the 2-year steer ADG was similar, market price per hundredweight was $0.26/lb greater year-2 compared to year-1 ($1.37 vs. $1.63). Year-1 steer gain value/steer/ac, after deductions for freight and sale barn marketing charges, was $29.83/ac; and year-2, due to the higher market prices for yearling steers, the gain value/steer/ac was $93.74. The two-year average lime cost/ac after accounting for steer gain value reduction was $58.21 and $178.21/ac for the 2 and 4Ton application rates.

Soil samples were collected on October 28, 2021, (0-3in) in corn (CN), sunflower (SF), spring wheat (SPW), and cover crop (CCRP) fields from designated sampling strips identified as A3 through A8, which included two reps from untreated check, 2T, and 4T treatment strips. Soil samples were analyzed by Ward Laboratories, Inc., Kearny, NE, for microbial biomass and arbuscular mycorrhizal fungi (AMF) using the phospholipid fatty acid (PLFA) Soil Microbial Community Analysis. Measurement units are expressed in nanograms/gram of soil. The Haney Soil Health Analysis provided results for soil pH (H^+ ion concentration; 1:1 soil:water ratio), organic matter (OM %), and nitrate-NO_3-N (ppm).

Microbial testing revealed a sharply greater microbial biomass (Fig. 1, ng/g soil) in the cover crop (CCRP) treatment strips. The CCRP check and 4T treatment strips had the highest microbial biomass. Interestingly, the CCRP check strip had the highest microbial biomass (10693 ng/g), but also a pH level of 4.85, which indicates tolerance for soil acidity. Except for the SPW 2T strip, all other crops and treatment levels were considerably lower. Likewise, arbuscular mycorrhizal fungi AMF (Fig. 2) levels mirrored the PLFA values, i.e., check strip and 4T levels were highest followed by 2T strip and the SPW 2T was also high.

The 2T and 4T beet lime applications consistently increased soil pH values (Fig 3) compared to the check strips among all crops. The 2T and 4T cover crop pH values were consistently higher than the check strip indicating that yearling steer hoof action may have been effective for lime incorporation.

Soil organic matter (Fig 4) level on the Thomas Family Farm, Mott, North Dakota, is consistently very good ranging from a low of 3.1 to 4.35%. This range of organic matter across crops demonstrates the value of a diverse crop rotation, which followed a consistent trendline from the check strip through 2T and 4T treatment levels with the exception of SF in which check strip was higher than the 4T application.

Residual nitrate levels (Fig 5) were consistently and significantly higher for CN check, 2T and 4T strips as well as the 2T SPW strip. These residual levels are consistent with the farm producers N fertilizer applications on corn.

Considering the data results, it appears that the yearling steer hoof action may have had a positive impact on the soil environment and yearling steer gain value over the first two years of the study contributed to offsetting the cost of lime and application. A third year of the long-term study will be continued during the 2023 growing season.

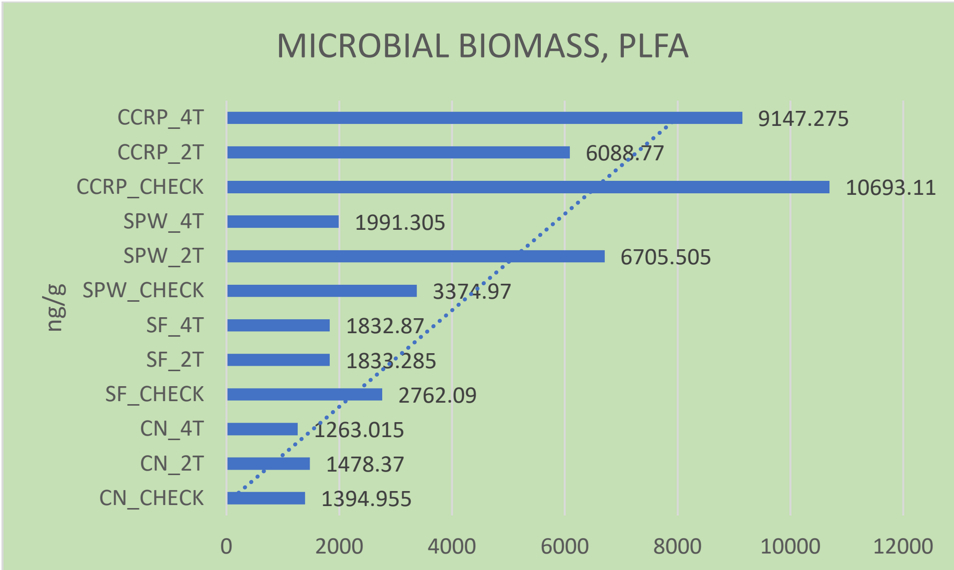

MICROBIAL BIOMASS, PLFA
ng/g
CCRP_4T
CCRP_2T
CCRP_CHECK
SPW_4T
SPW_2T
SPW_CHECK
SF_4T
SF_2T
SF_CHECK
CN_4T
CN_2T
CN_CHECK
9147.275
6088.77
10693.11
1991.305
6705.505
3374.97
1832.87
1833.285
2762.09
1263.015
1478.37
1394.955
0
2000
4000
6000
8000
10000
12000

Fig. 1

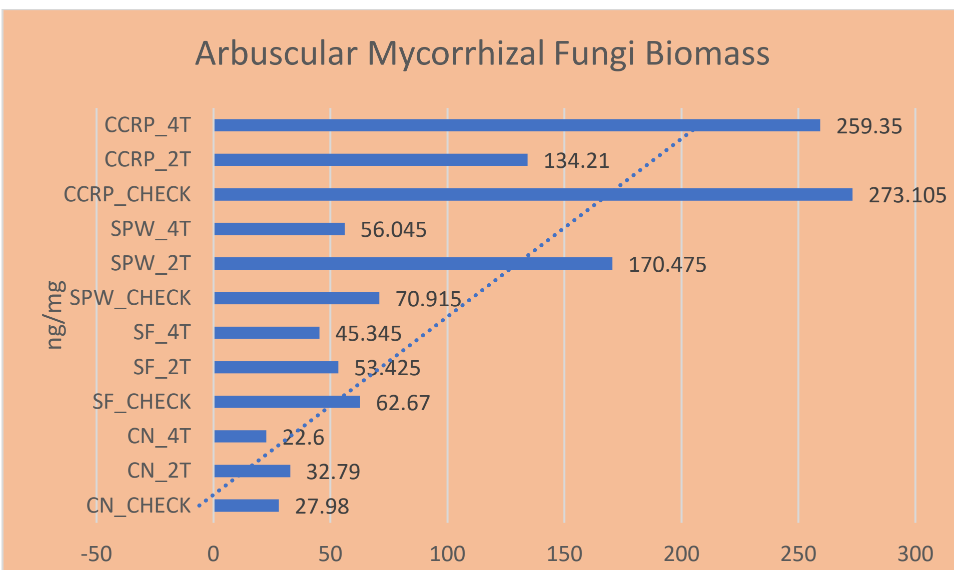

Arbuscular Mycorrhizal Fungi Biomass
ng/mg
CCRP_4T
CCRP_2T
CCRP_CHECK
SPW_4T
SPW_2T
SPW_CHECK
SF_4T
SF_2T
SF_CHECK
CN_4T
CN_2T
CN_CHECK
259.35
134.21
273.105
56.045
170.475
70.915
45.345
53.425
62.67
22.6
32.79
27.98
-50
0
50
100
150
200
250
300

Fig. 2

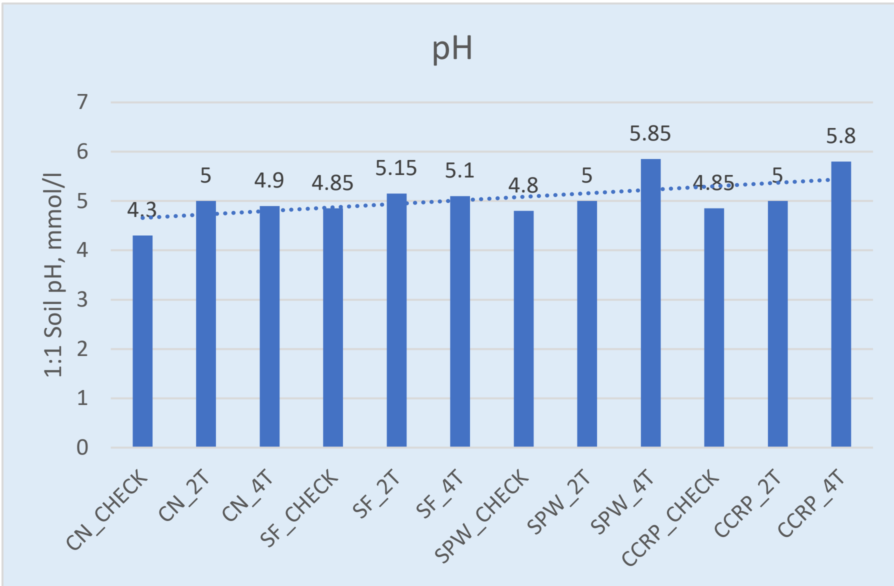

pH
1:1 Soil pH, mmol/l
7
6
5
4
3
2
1
0
4.3
5
4.9
4.85
5.15
5.1
4.8
5
5.85
4.85
5
5.8
CN_CHECK
CN_2T
CN_4T
SF_CHECK
SF_2T
SF_4T
SPW_CHECK
SPW_2T
SPW_4T
CCRP_CHECK
CCRP_2T
CCRP_4T

Fig. 3

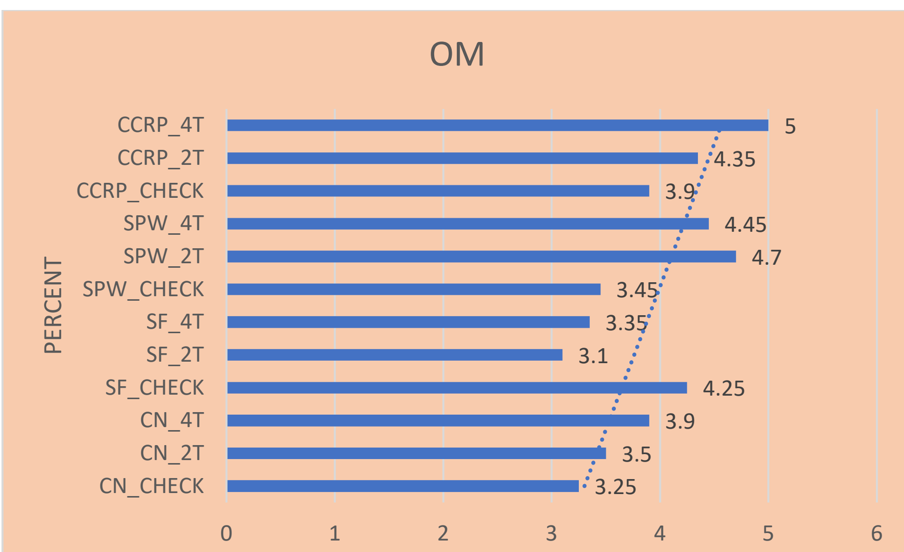
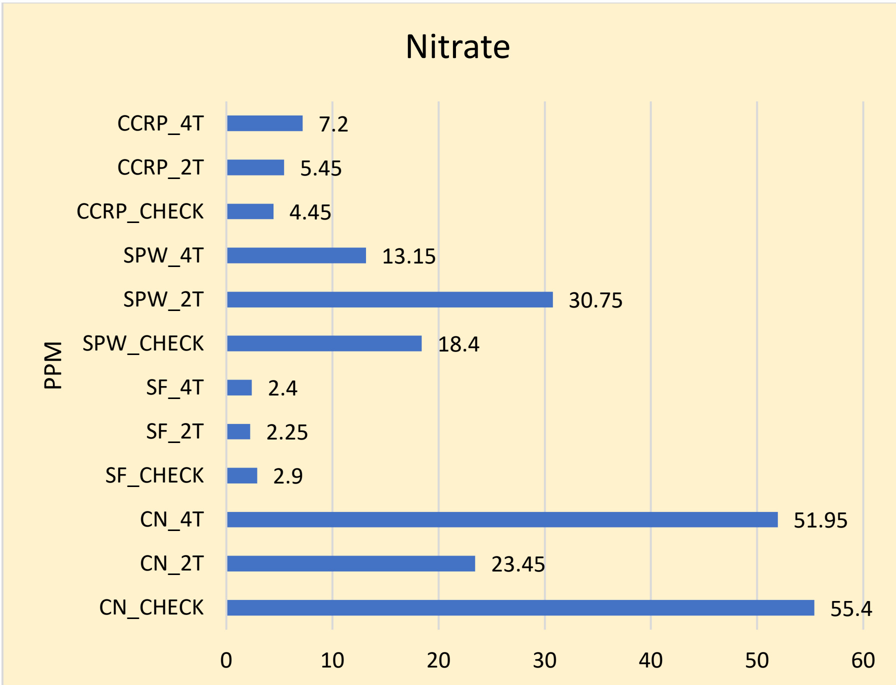

OM
PERCENT
CCRP_4T
CCRP_2T
CCRP_CHECK
SPW_4T
SPW_2T
SPW_CHECK
SF_4T
SF_2T
SF_CHECK
CN_4T
CN_2T
CN_CHECK
5
4.35
3.9
4.45
4.7
3.45
3.35
3.1
4.25
3.9
3.5
3.25
0
1
2
3
4
5
6

Fig. 4


Nitrate
CCRP_4T
CCRP_2T
CCRP_CHECK
SPW_4T
SPW_2T
SPW_CHECK
SF_4T
SF_2T
SF_CHECK
CN_4T
CN_2T
CN_CHECK
PPM
7.2
5.45
4.45
13.15
30.75
18.4
2.4
2.25
2.9
51.95
23.45
55.4
0
10
20
30
40
50
60
Fig. 5