Corn Silage Yield and Quality, and Soil Health Metrics After Fall Cover Crop Grazing

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Abstract: Integrated crop-livestock systems can potentially produce more product per unit of land with minimal impacts on soil health and cash crop quality. In the Upper Midwest there is an opportunity to graze fall cover crops (CC) after winter wheat in a corn-wheat rotation. In East Lansing, Michigan, two CC treatments: 1) a pure brassica mixture (PURE), and 2) a complex mixture containing legumes, warm and cool season grasses, and brassicas (MIX) were planted after wheat, and grazed by lambs in the fall seasons of 2019 to 2021. The following year, soil health, corn yield and quality were measured from plots corresponding to a non-grazed control and plots grazed in October, November, and December. There was no significant effect on spring soil bulk density and penetration resistance (PR) regardless of CC mixture or the timing of grazing, although PR was numerically higher in the grazed plots. Corn crude protein, acid detergent fiber, and neutral detergent fiber were not different across graze date or CC treatments ($P > 0.05$), although corn contained more starch when grown after MIX grazed in November ($P=0.02$). The difference in starch was possibly an artefact of spatial variability across the site. Corn dry matter yield was lower in the non-grazed control (15.35 Mg ha^{-1}) when compared to the grazing treatments in October (17.37 Mg ha^{-1}) and December (17.19 Mg ha^{-1}) ($P=0.03$). Grazing cover crops in the fall may improve corn yield the following year without causing soil compaction or changing corn quality.

Introduction

As demand for animal and crop products increases, there is a growing need for sustainable intensification of current agronomic systems. Integrated crop-livestock systems (ICLS) are a set of management practices that aim to incorporate livestock back into crop production systems either spatially or temporally. Common models for this management practice are grazing cash crop stover, rotating crop fields with forage pasture, and applying manure. While these methods have proven to be beneficial, they come with the drawback of either providing low quality forage or removing a field from production of more profitable crops. One potential avenue of integrating high quality forage into cash crop production systems is grazing annual cover crops. This comes with the added benefit that cover crops can provide a range of ecosystem benefits by protecting the soil surface, scavenging nutrients, and attracting pollinators. One of the largest barriers to wider cover crop adoption outside of ICLS is the cost associated with managing crops that will provide no immediate monetary gain, as it takes years for cover crops to improve soil health to a noticeable degree (Wang, 2020). Implementing annual cover crops in ICLS may provide opportunities for row-crop farmers to lease cover crop pastures to livestock producers, offsetting the costs of cover-crop planting and maintenance.

Positive or negative outcomes from cover crop ICLS are highly dependent on crop and livestock management practices, climate, and soil type. For example, a study in the southeast US found that grazing cover crops can potentially increase microbial carbon under no-tillage conditions while other soil health indicators were not affected (Franzluebbers and Stuedemann, 2015). Another study in the southern US showed that grazing cattle on cover crops can reduce water infiltration and increase bulk density, although not to a detrimental degree (Franzluebbers and Stuedemann 2008).

In the upper Midwestern U.S., the fallow period after wheat harvest provides an ideal opportunity for cover crop grazing. In East Lansing, Michigan, we conducted a study with two objectives: 1) evaluate lamb performance when finished for slaughter on cover crops and 2) evaluate soil health and corn performance in the subsequent silage corn rotation. The first objective is reported elsewhere (Macaluso, 2020; Eckhardt et al., 2022) and the second is presented herein.

Methods

In this RCBD, cover crop strips were planted from 2019-2021 with three replications of two cover crop mixtures: 1) a pure brassica mixture (PURE) consisting of tillage radish (*Raphanus sativus*), turnip (*Brassica rapa subsp Rapa*), and rape (*Brassica napus*) and 2) a complex mixture (MIX) containing all three of those brassicas in addition to oats (*Avena sativa*), annual ryegrass (*Lolium multiflorum)*, pearl millet (*Pennisetum glaucum*), Japanese millet (*Echinocola esculenta*), field pea (*Pisum sativum*), and berseem clover (*Trifolium alexandtrinum*). Lambs strip-grazed the cover crops for eight weeks from October to December. The following spring, soil health measurements and samples collected from subplots corresponding to non-grazed areas and areas grazed in October, November, or December. Corn (*Zea mays L.*) was planted on May 2021, and June 2022 following the cover cropping period.

Soil health data was collected in the spring before corn silage planting from 2019 – 2022. Penetration resistance was collected using a FieldScout penetrometer using the 1/2in diameter probe. PSI readings were collected by the instrument every inch from 0-18 inches in depth. For this report, we will focus on the readings from 0-10 inches (0-30cm) as we hypothesize that the compaction effects from hoof traffic would not exceed the shallow depths and any changes in penetration resistance will be attributed to subsoil heterogeneity. Soil bulk density was collected using a slide-hammer attached to a 5-cm diameter sampling cup, and gravimetric soil moisture content was recorded from a subsample of the bulk density soil samples.

Corn yield and nutritive value metrics were collected when corn reached ~65% moisture content. Total green yield was determined by hand cutting (15 cm cut height) and weighing 3 m of two adjacent planting rows. A subset of 10 stalks from each plot were chopped in a woodchipper and subsamples of chopped forage were oven dried at 65C and weighed to determine dry matter percentage. Dry yield was determined by multiplying DM percentage by total green yield. Nutritive value of dry forage samples was analysed using near-infrared reflectance spectroscopy with fresh corn silage calibrations from the NIRS Forage Consortium (NIRSC, Berea, KY).

Statistical analysis was done in R version 4.1.1 using the Linear Mixed Effects Models package (nlme). The effects of grazing time, cover crop, and their interaction was tested using a combination of analysis of variance and the Emmeans package. Soil penetration resistance was analysed using nlme, and data was sliced across depth to compare the effects of each study factor.

Results and Discussion

Soil Health

There was no significant difference in bulk density between treatments regardless of cover crop and the time the paddock was grazed. Soil PR also yielded no significant results across cover crop treatment or the month the paddock was grazed, nor did any PR measurements meet or exceed the 2000 kPa threshold that would inhibit root growth. However, plots that had received a grazing treatment have a slightly higher penetration resistance than the non-grazed control. Additional soil health metrics will be measured, such as permanganate oxidizable carbon, total C and N, and wet aggregate stability.

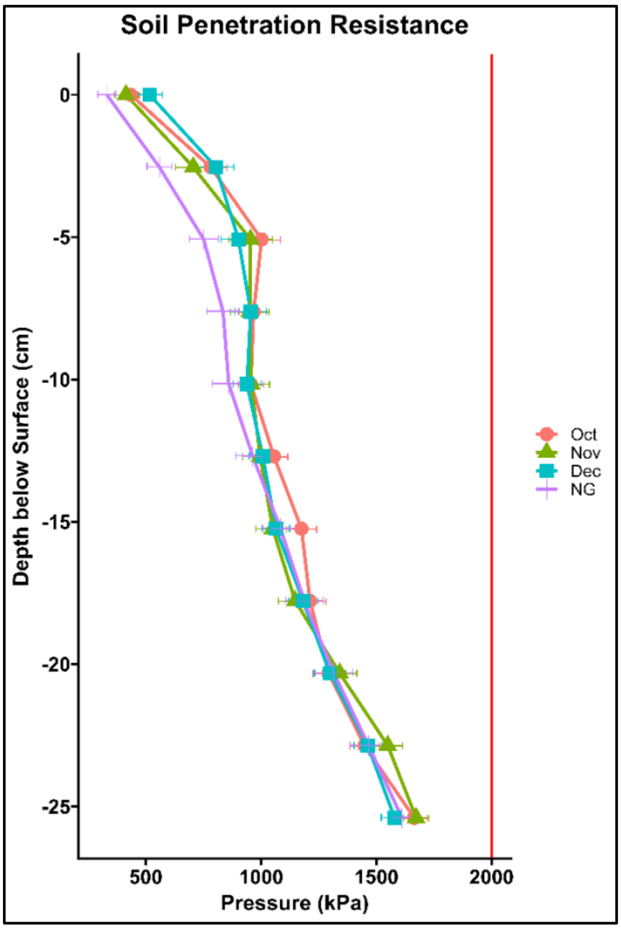

Figure 1: Soil penetration resistance in kPa from the soil surface down to 30cm in depth. Cell means of the graze date were compared across each depth with the non-graze control represented in purple, October in red, November in green, and December in blue. Line at 2000 kPa denotes the critical pressure threshold that may impede root development.

Corn Silage Yield and Nutritive Value

There were no differences across cover crops or timing of grazing for ADF, NDF, and crude protein (Fig. 2, $P>0.05$). However, starch content was higher in paddocks planted with the complex mixture when compared to the pure brassica mixture when grazed in November (cover crop * timing interaction, $P<0.05$). Any contributions that the cover crop and timing of grazing treatments may have had on soil fertility were overshadowed by application of manure in the spring and foliar nitrogen application to the corn at V4. The difference in starch content is likely attributed to spatial heterogeneity of the study plots either through weed pressure or soil conditions. Further analysis will need to be done to determine if the grazing treatments had any effect on weed biomass and richness as grazing may have had an impact on the lifecycle of winter annual weeds.

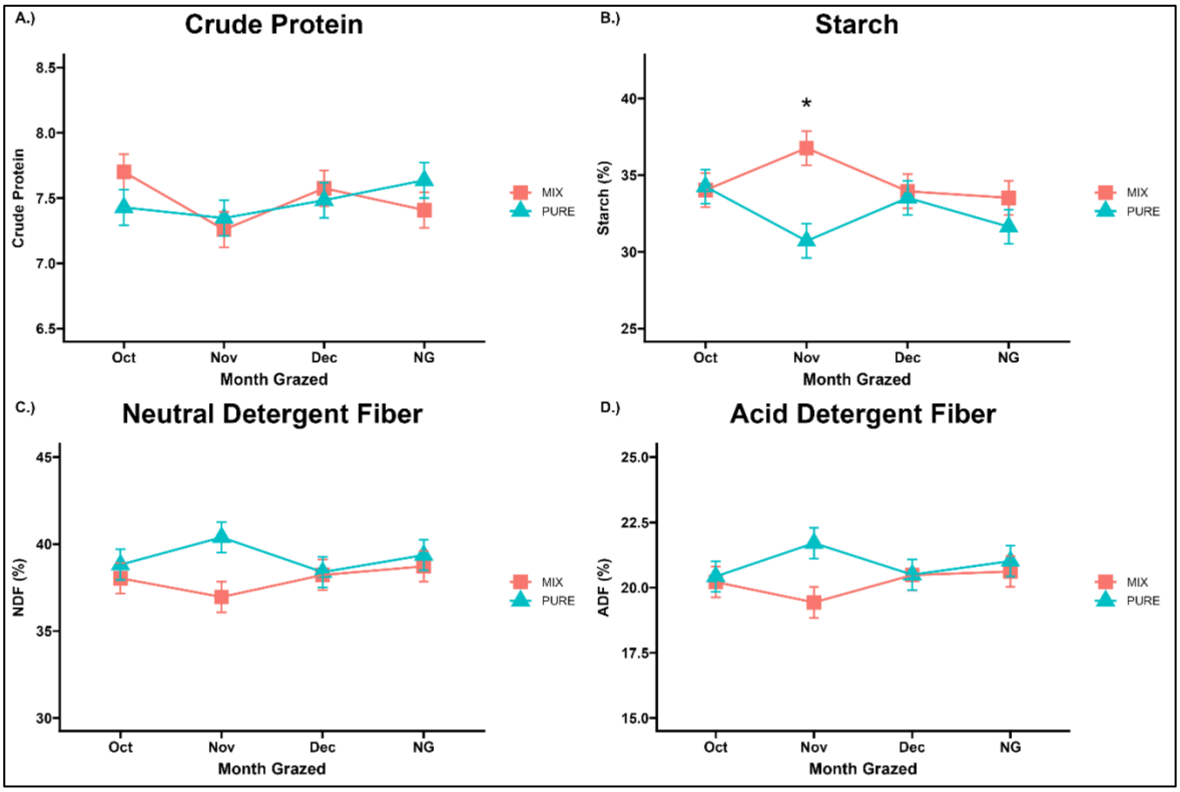

Figure 2: Corn quality of percent Crude Protein (A), Percent Starch (B), Percent Neutral Detergent Fiber (C), and Percent Acid Detergent Fiber (D). Multiple comparisons were done using Fishers LSD and significance is denoted by asterisks.

Corn dry matter yield was significantly greater in plots grazed the previous Oct and Dec (17.37 Mg ha^{-1} and 17.19 Mg ha^{-1} respectively) when compared to the NG control at 15.35 Mg ha^{-1} (Fig. 3). All grazing treatments were numerically higher than the non-grazed control when compared across graze timings. We hypothesize that beneficial effects of grazing may be from the effects of lamb manure providing more plant available nutrients and labile carbon suitable for stimulating microbial communities. Further analysis will need to be done to determine the effect of soil heterogeneity in texture and soil organic matter as well as heterogeneity in weed pressure across the fields.

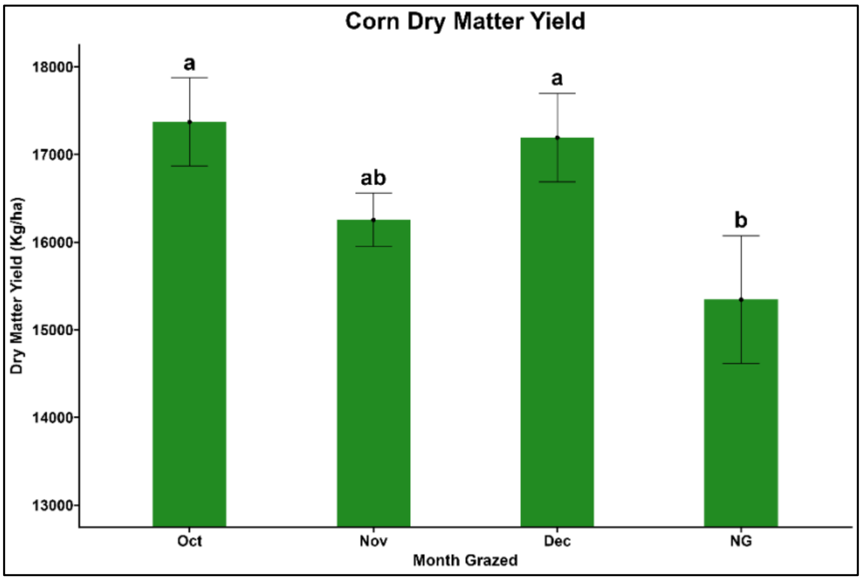

Figure 3: Corn silage dry matter yield across grazing date. Comparisons were done using Fishers LSD and columns that share a letter designation are not significantly different than one another (P>0.05)

Conclusions and/or Implications

Our results demonstrate that grazing lambs on annual cover crops the fall before growing corn does not lead to soil compaction at the time of subsequent corn planting. Grazing lambs may increase corn silage yield compared to non-grazed cover crops, and the highest yields were found when paddocks were grazed in

October and December. Grazing lambs on cover crops did not directly reduce subsequent corn silage quality. The difference found in starch content is most likely due to heterogeneity in weed pressure. There may be some treatment effect on the weed populations either by grazing interfering with weed life cycles or the complex cover crop mixture having a greater effect on weed suppression. Further analysis will need to be done to determine the covariate effects of climate, weed pressure, and soil heterogeneity on our response variables.

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