Optimizing Dryland Processing Sweet Corn Production through Improved Nitrogen Management: Three Year Summary

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Carl Rosen[1], James Crants[1], Matt McNearney[1], Vince Fritz[2], and Charlie Rohwer[2]
[1]Department of Soil, Water, and Climate, [2]Southern Research and Outreach Center;
University of Minnesota

Abstract

Optimal nitrogen (N) management for new sweet corn hybrids may require different N application rates or methods or different population densities than current published guidelines recommend. The effectiveness of N fertilization may also be influenced by the time when corn is planted and fertilizer is applied, because N mineralization rates are higher later in the planting season, potentially decreasing the optimal N application rate. The objective of this three-year study was to determine the effects of N application rate and method, hybrid, population density, and planting date on sweet corn yield and N use. We evaluated three hybrids (DMC 21-84, GSS 1477, and GM Code 646) planted at two times (May and June), thinned to one of two density categories (targeted densities of 28,000 or 22,000 plants/ac), and receiving six N treatments: (1) no N applied, (2) 60 lbs N/ac applied preplant as urea, (3) 120 lbs N/ac applied preplant as urea, (4) 180 lbs N/ac applied preplant as urea, (5) 120 lbs N/ac applied preplant as ESN, and (6) 120 lbs N/ac as urea with 60 lbs N/ac applied preplant and 60 lbs N/ac applied at V6–V8. Both cut and green yield increased with increasing N rate, with the response to increasing N weakening but not leveling off between 120 and 180 lbs N/ac. The yield response to N rate was stronger in high-density plots, but did not vary significantly among the hybrids or between the two planting months. However, based on cut yield and green yield, GM Code 646 outperformed the other two hybrids in this study. Yield at an N rate of 120 lbs/ac was not affected by whether the N was applied in a single application of urea preplant, as ESN preplant, or in split applications of urea. Above-ground N uptake increased with N rate, especially in high-density plots and in plots planted in May; this relationship did not differ significantly among the three hybrids. As was the case for yield, N uptake at an N rate of 120 lbs/ac was not affected by the form or timing of N application. The proportion of N that was incorporated into the stover decreased with N application rate, with most of the response occurring between 0 and 60 lbs N/ac. The use of ESN or split applications at 120 lbs N/ac decreased the percentage of N incorporated into the stover relative to the use of a single preplant urea application, suggesting that N received preplant is more likely to be incorporated into the stover (instead of the ears) than N received later. N use efficiency decreased as the application rate of N increased among plots with high population density. This relationship was not related to the hybrid used. The use of ESN or split applications at 120 lbs N/ac had no effect on N use efficiency. Residual soil NO_3-N concentration was unrelated to planting month but increased with N rate. Our yield results suggest that the optimal N application rate for non-irrigated sweet corn following soybean on soils high in organic matter is in the range of 120 to 180 lbs N/ac, substantially higher than the currently recommended 110 lbs N/ac. The hybrids used in this study did not differ in their yield or N use responses to N treatment, contrary to our expectations. We found almost no effect of applying N as ESN preplant or in split applications of urea instead of a single preplant urea application, except for a decrease in the percentage of tissue N incorporated into the stover (equivalently, an increase in the percentage incorporated into the ears). In plots receiving at least 120 lbs N/ac, the stover had C:N ratios of 32:1 to 35:1. These relatively low ratios and the large amount of N left in the stover (from 70 to 77 lbs N/ac in the treatments receiving at least 120 lbs N/ac) suggest that there may be an N credit for field corn following sweet corn.

Background and Justification

Nitrogen (N) recommendations for non-irrigated processing sweet corn production in high organic matter soils have been established for many years. However, these recommendations are based on varieties that are no longer used in commercial production. Varieties in current use have improved agronomic traits, often including improved N use efficiency.

The general management practice for sweet corn on dryland soils is to apply N fertilizer in the spring before planting. However, few studies have evaluated sweet corn response to split applications or newer fertilizer products such as coated urea fertilizers. With increasing costs of N for crop production and its susceptibility to losses into the environment (leaching, runoff, volatilization), improving N management practices will optimize both production and environmental stewardship.

Population density is an important factor in both maximizing yield and minimizing N losses. Across a wide range of population densities, per-acre N uptake increases with density, but the optimum density for maximizing yield is lower than the optimum for maximizing N uptake. Identifying varieties that tolerate, and even flourish in high population densities is a high priority, with a goal of maximizing production efficiencies.

Nitrogen mineralization rate increases with soil temperature. Processing sweet corn is planted over a two-month window. Planting date is therefore another key factor to consider in sweet corn management. We hypothesized that optimal N fertility rate would most likely be lower for sweet corn planted after June 1 compared with a planting date in early May, due to the higher N mineralization rates later in the season.

The overall goal of this research is to improve N fertilizer management practices for non-irrigated processing sweet corn on high organic matter, fine textured soils. The specific objective is to determine the effects of N rate and timing, hybrid, plant population density, and planting date on sweet corn yield, N uptake, N use efficiency, and end-of-season residual soil N. Compiled results from three years (2014-2016) are presented.

Materials and Methods

Experimental plots were established in Nicolett-Webster clay loam soils at the Southern Research and Outreach Center in Waseca in 2014, 2015, and 2016. The previous crop was soybean in each year.

Six N treatments were evaluated: (1) 0 N (no N applied), (2) 60 lbs N/ac applied preplant as urea, (3) 120 lbs N/ac applied preplant as urea, (4) 180 lbs N/ac applied preplant as urea, (5) 120 lbs N/ac applied preplant as ESN, and (6) 120 lbs N/ac as urea with 60 lbs N/ac applied preplant and 60 lbs N/ac applied at V6–V8.

The three sweet corn hybrids evaluated were: GSS 1477, DMC 21-84, and GM Code 646.

Seeds were planted on 23 May and 24 June in 2014, 1 May and 19 June in 2015, and 18 May and 14 June 2016. We seeded at 30,600 – 32,900 seeds per acre and thinned to 22,070 or 27,878 plants/ac after emergence. For data analysis, we classified plant density treatments as 'low' (<25,000/ac) or 'high' (>25,000/A) because of uneven emergence in 2015 and 2016.

For each planting date, preplant fertilizer was applied 1 to 7 days before planting. At planting, 6.5 gal/ac of 10-34-0 fertilizer was applied in furrow over the seed.

The experiment was laid out as a split-split plot in a randomized complete block design with four replicates. Each plot consisted of four rows 30 ft. long with 2.5 feet between rows. Whole plots were defined by planting date and hybrid, while sub-plots were defined by N rate, and population density defined the sub-sub-plots. A total of 144 plots were evaluated for each planting date.

Twenty feet from the middle two rows were machined harvested 88 to 117 days after planting, targeting kernel moisture of 76%. At harvest, the following performance indicators were measured: unhusked and husked yield, ear length, ears usable as corn-on-the-cob sections, and cut corn yield. The N concentrations of all aboveground plants parts were measured in 2014 and 2015 with a Vario EL CNS combustion analyzer.

Soil samples to a depth of two feet were collected in October of each year from each combination of planting date and N treatment. Samples were dried at 95°F for 48 hours, ground, and evaluated for NO_3-N concentration using a Wescan N analyzer.

The data were analyzed using the MIXED procedure with SAS 9.4m software (SAS Institute, 2015). The data from all three years were pooled. Soil NO_3-N data were analyzed with planting month, N treatment, month*N treatment, and year as fixed effects, and block-within-year as a random effect. Yield and N uptake data were analyzed with planting month, hybrid, N treatment, population density, their two-way interactions, and year as fixed effects, and block-within-year as a random effect. Categorical means, 95% confidence intervals, and pairwise comparisons between categories were generated using the LSMEANS statement with the ALPHA=0.05 and DIFF options. We used the Satterthwaite method for determining denominator degrees of freedom.

Sub-sub-plots with plant densities less than 19,000 plants/ac and those with long-term flooding were excluded from yield and N uptake analyses. However, end-of-season soil samples were collected without regard to plot flooding or realized population density, and low-density and flooded plots could therefore not be excluded from the analysis of this variable.

Results

Yield

Cut yield, green yield, and mean ear length were related to the interactions of population density with planting month, hybrid, and N treatment.

Effects of the interaction between population density and planting month are presented in Figure 1. Among plots planted in May, cut yield was lower at high population density than at low density. A non-significant trend in the opposite direction was observed in plots planted in June, which had slightly higher cut yields overall. Similar effects were observed for green yield, except that the positive effect of high density on yield in June-planted plots was significant, as was the difference in yield between May-planted and June-planted plots when population density was high. Ear length was shorter at high population density among the May-planted plots, with a trend in the same direction among June-planted plots.

Effects of the interaction between population density and hybrid are presented in Figure 2. The hybrid GM Code 646 had higher cut and green yields and greater mean ear length than DMC21-8 or GSS1477 at either population density. While density had no significant effect on cut or green yield for GM Code 646, yield decreased with density in DMC21-8 and increased with density in GSS1477. All three hybrids had shorter ear lengths at high density. The hybrid DMC21-8 had higher green yield, but not cut yield, than GS1477 at low population density. Based on both cut yield and green yield, the hybrid GM Code 646 clearly outperformed the other two hybrids in this study

Effects of the interaction between population density and N treatment are presented in Figure 3. While cut yield, green yield, and mean ear length increased with N application rate regardless of population density, the response was much stronger at high density. High-density plots had significantly lower yields than low-density plots when no N was applied, but had similar or slightly greater yields and at higher N application rates. Ear length was consistently shorter in high-density than low-density plots, but the difference diminished as the application rate of N increased.

Ear length was related to the interaction between planting month and N treatment (Figure 4). Ear length was more responsive to N application rate among May-planted plots than it was among June-planted plots, so that May-planted plots had significantly shorter ears than June-planted plots when no N was applied, but slightly longer ears when N was applied at 120 or 180 lbs/ac.

N uptake

Tissue N concentrations have only been determined for 2014 and 2015, and results for N uptake and N use efficiency therefore include only data from these years.

N uptake did not vary significantly among the three hybrids ($P = 0.1661$).

Plots with high population density showed a much stronger response of N uptake to N application rate than those with low population density (Figure 5a). While density had little effect on N uptake when no N was applied, high-density plots took up significantly more N than low-density plots in all other N treatments. Whether the N was applied at 120 lbs N/ac in a single application of urea or ESN or in split applications of urea had no significant effect on N uptake.

Plots planted in May showed a much stronger N uptake response to N application rate than those planted in June (Figure 5b). Planting month had little effect on N uptake when N was applied at 0 or 60 lbs/ac. However, at the 120 lbs N/ac rate, plots planted in May had greater uptake than those planted in June, regardless of whether N was applied as a single application of urea, a single application of ESN, or two applications of urea.

On average, about 60% of the N taken up was incorporated into the stover, suggesting that a significant portion of N applied to a field remains in the field as stover after harvest.

The percentage of N uptake represented by stover differed among the three hybrids (Figure 6), with DMC 21-B having more of its N in the stover than GM Code 646.

The percentage of N in the stover decreased as N application rate increased (Figure 7). Interestingly, while applying N as ESN or in split applications had little effect on most variables, both of these treatments had numerically lower percentages of the N taken up incorporated into stover than did the treatment receiving N as a single application of uncoated urea at the same rate. This difference was significant for the split-application treatment.

The interaction between planting month and population density had a significant effect on the percentage of N taken up that was incorporated into stover (Figure 8). High-density plots incorporated a larger percentage of N taken up into stover than low-density plots, and May-planted plots incorporated more of their N into stover than June-planted plots. The effect of density was stronger in May-planted plots than in June-planted plots.

N use efficiency

Nitrogen use efficiency (the proportion of N applied to the field that is taken up by the plants) was related to the interaction between population density and planting month (Figure 9a). It was higher for May-planted plots than for June-planted plots, and for high-density plots than low-density plots. The effect of plot density was greater for May-planted plots than June-planted plots, resulting in a significant effect of the interaction between planting month and population density.

The relative N use efficiencies of the different hybrids depended on population density (Figure 9b). At low density, DMC 21-8 had significantly greater N use efficiency than either of the other two hybrids. However, at high density, DMC 21-8 and GSS 1477 had similar N use efficiency to each other, with both having higher efficiency than GM Code 646. All hybrids had numerically higher N use efficiency at high density than low density.

N use efficiency declined significantly as the application rate of N increased, but only in the high-density plots (Figure 9c). Low-density plots exhibited no response of N use efficiency to application rate.

Of the three hybrids, GM Code 646 had the strongest response of N use efficiency to planting month (Figure 10). The N use efficiency of June-planted GM Code 646 was about half that of the other two hybrids planted in June, and less than half that of May-planted GM Code 646. The other two hybrids also had slightly lower N use efficiency when planted in June than May, but the difference was not significant in either case.

We had expected that some hybrids would lose less N use efficiency with increasing N application rate than others, which would be detected as a significant effect of the interaction between hybrid and N treatment on N use efficiency. This effect was not observed ($P = 0.4401$), and including only the treatments receiving a single application of uncoated urea did not change this ($P = 0.4944$). Because the high-density plots showed a response to N treatment and the low-density plots did not, we evaluated the high-density plots separately from the low-density plots, but there was no effect of the interaction between hybrid and N treatment on N use efficiency for either group, whether or not the treatments receiving ESN or split applications of urea were included.

Residual soil NO_3-N

Planting month had no significant effect on residual NO_3-N in the top two feet of soil (Figure 11), though June-planted plots had numerically greater concentrations than May-planted plots. This is consistent with the lower rates of N uptake observed in the June-planted plots at high N application rates, but also with the greater time available for NO_3-N losses between application and soil sampling in the May-planted plots.

Residual soil NO_3-N concentration generally increased with increasing N application rate (Figure 12). The treatments receiving 120 lbs N/ac as ESN or split applications of urea had similar soil NO_3-N concentrations to each other and to the treatment receiving the same rate of N as a single application of urea.

Conclusions

Previously published N fertilizer recommendations for sweet corn planted after soybeans in medium to high-organic-matter soils (Rosen and Eliason. 2005. Nutrient Management for Commercial Fruit & Vegetable Crops in Minnesota. University of Minnesota Extension) indicate that an N application rate of 110 lbs/ac should produce maximum green yield. In this study, green yield continued to increase with N application rate between 120 and 180 lbs/ac. The continued response of green yield to additional N beyond 110 lbs/ac may be a product of the improved hybrids used in this study relative to those available prior to 2005. These results suggest that N recommendations for processing sweet corn following soybean may need to be increased by 20-30 lbs N/ac to optimize yield.

Contrary to our expectations, the three hybrids used in this study did not differ significantly in their response to N treatment in any way. Population density, on the other hand, had a strong influence on the response of N use efficiency to N treatment, with only the high-density plots showing any response. However, regardless of N rate, density or planting date, cut yield and green yield of GM Code 646 outperformed the other two hybrids in this study.

We hypothesized that sweet corn would have a lower optimal N fertility rate if planted in June rather than May. However, we did not find an effect of the interaction between planting month and N treatment on yield or N use efficiency. However, we did find that the response of N uptake to N application rate leveled off at 120 lbs N/ac in June-planted plots but kept increasing in May-planted plots.

The majority of the N taken up by the plants was incorporated into the stover and therefore left in the field after harvest; between 70 and 77 lbs N/ac was found in the stover among the treatments receiving at least 120 lbs N/ac. However, the C:N of the stover ranged from 41:1 for the zero-N control plots to 32:1 in the plots receiving 180 lbs N/ac, suggesting that stover incorporated in the stover will have a delay in N mineralization. Because most commercially grown sweet corn will be fertilized with N, the C:N ratio will be closer to 32 than 41; all treatments receiving at least 120 lbs N/ac had C:N ratios between 32 and 35. For comparison, the C:N ratio of field corn stover is 57, almost twice that of sweet corn stover. The lower C:N ratio of sweet corn stover as well as the high amounts of N still remaining in the stover relative to field corn suggests that there might be an N credit for field corn following sweet corn. Determining if an N credit can be provided for crops following sweet corn will the subject of future studies.

The percentage of above-ground tissue N incorporated in the stover (as opposed to the ears) was somewhat lower for the treatments receiving ESN or split applications of urea than for the treatment receiving a single application of urea at the same N rate. The ESN and split-application treatments received a portion of their N after planting. Perhaps N applied later in the season is more likely to be available for translocation into the ears than N applied preplant, resulting in a larger percentage of total N uptake incorporated into the ears and, conversely, a lower percentage incorporated into the stover for these treatments.

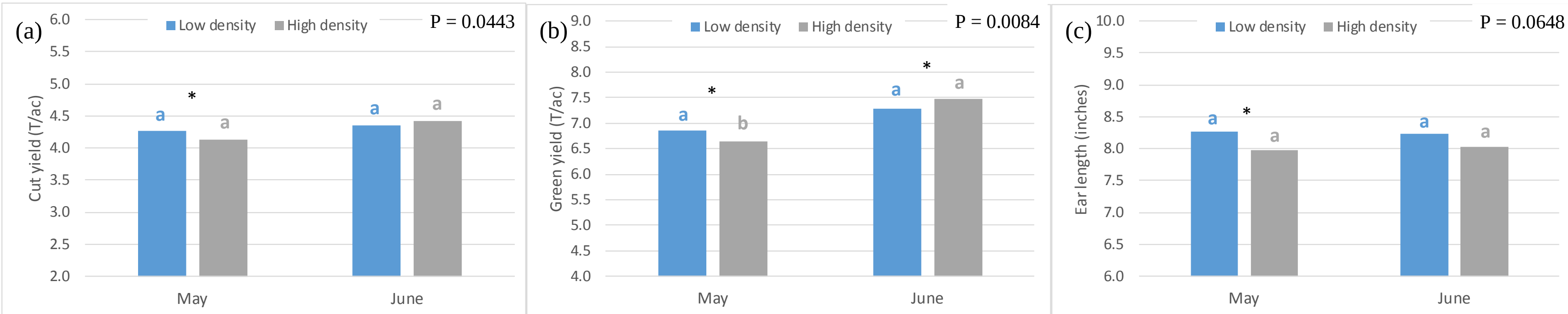

Figure 1. Effects of the interaction between planting month and population density on cut yield (a), green yield (b), and mean ear length (c). Asterisks (*) indicate that the effect of population density was significant for plots planted in the corresponding month. Letters indicate whether planting month had a significant effect at a given density; columns within a chart that share a letter of the same color are not significantly different.

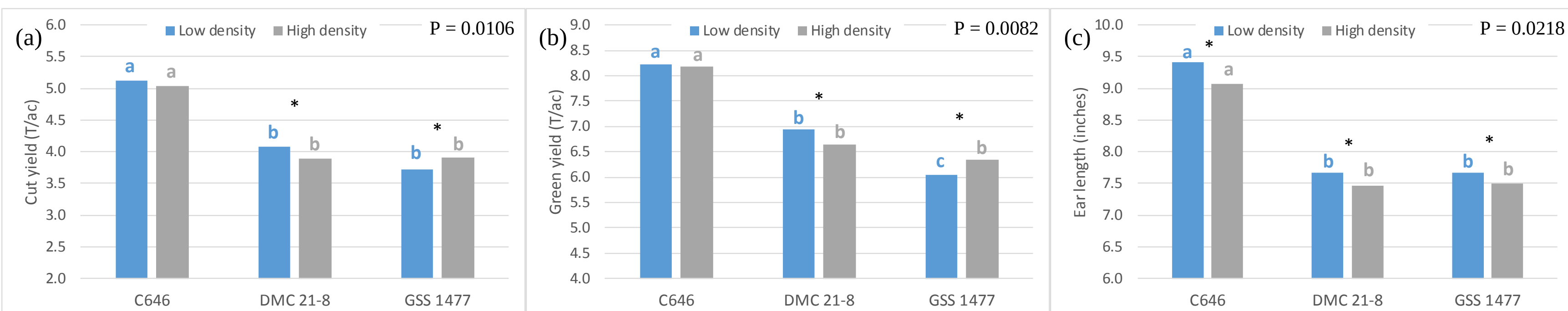

Figure 2. Effects of the interaction between hybrid and population density on cut yield (a), green yield (b), and mean ear length (c). Asterisks (*) indicate that the effect of population density was significant for the corresponding hybrid. Letters indicate whether hybrid had a significant effect at a given density; columns within a chart that share a letter of the same color are not significantly different.

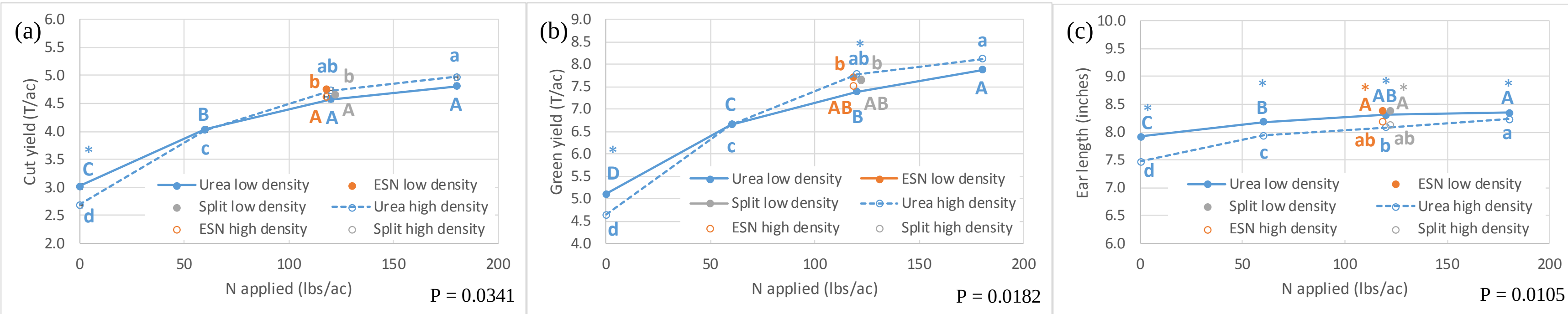

Figure 3. Effects of the interaction between N treatment and population density on cut yield (a), green yield (b), and mean ear length (c). Asterisks (*) indicate that population density had a significant effect within a given N treatment. Letters indicate effects of N treatment at a given population density, with capital letters used for low-density plots and lowercase letters used for high-density plots. Points on the same chart that share a common letter in the same case are not significantly different from each other.

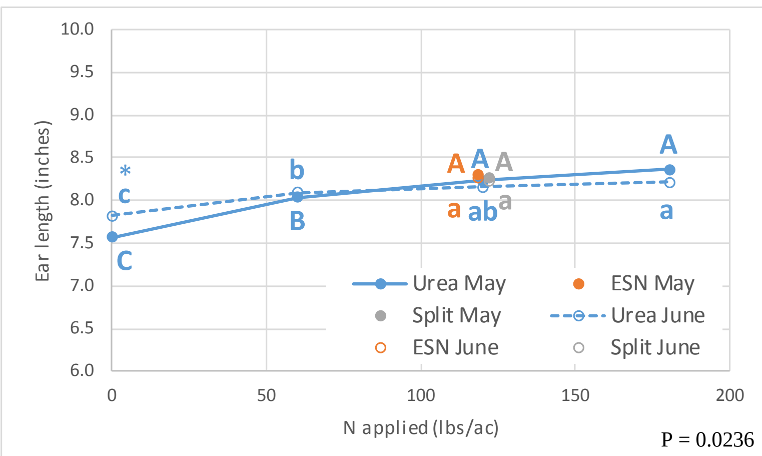

Figure 4. Effect of the interaction between N treatment and planting month on mean ear length. Asterisks (*) indicate that planting month had a significant effect within a given N treatment. Letters indicate effects of N treatment within a planting month, with capital letters used for May-planted plots and lowercase letters used for June-planted plots. Points that share a common letter in the same case are not significantly different from each other.

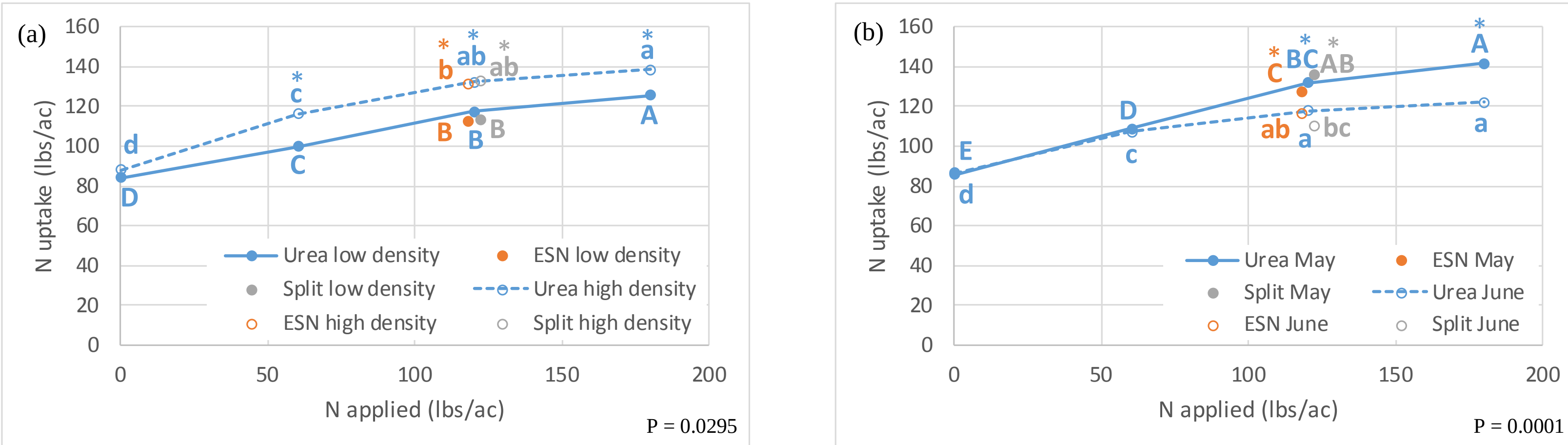

Figure 5. Effects of (a) the interaction between population density and N treatment and (b) the interaction between planting month and N treatment on N uptake. Asterisks indicate that density or planting month was significantly related to N uptake within a given N treatment. Letters indicate significant differences among N treatments within a population density or planting month. Capital letters are used for low-density plots or plots planted in May, while lowercase letters are used for high-density plots or plots planted in June. Points on the same chart that share a common letter in the same case are not significantly different from each other.

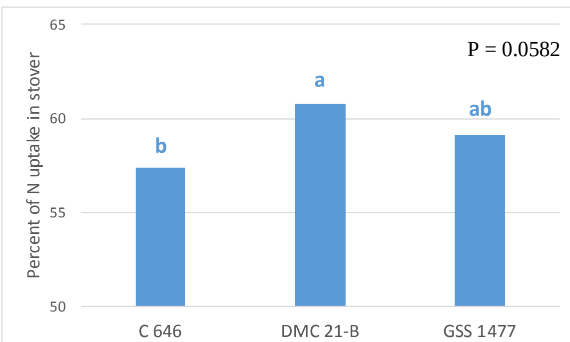

Figure 6. Effect of hybrid on the percentage of N taken up that is incorporated into the stover. Values that share a common letter are not significantly different.

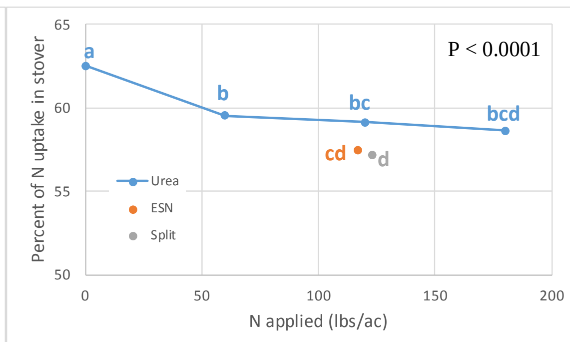

Figure 7. Effect of N treatment on the percentage of N taken up that is incorporated into the stover. Values that share a common letter are not significantly different.

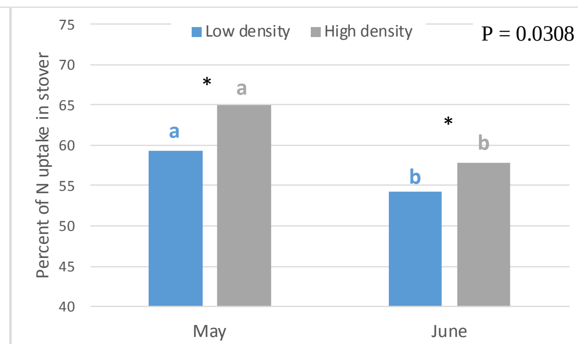

Figure 8. Effect of planting month and population density on the percentage of N taken up that is incorporated into the stover. Columns that share a common letter of the same color are not significantly different. Asterisks indicate a significant effect of density within the planting month.

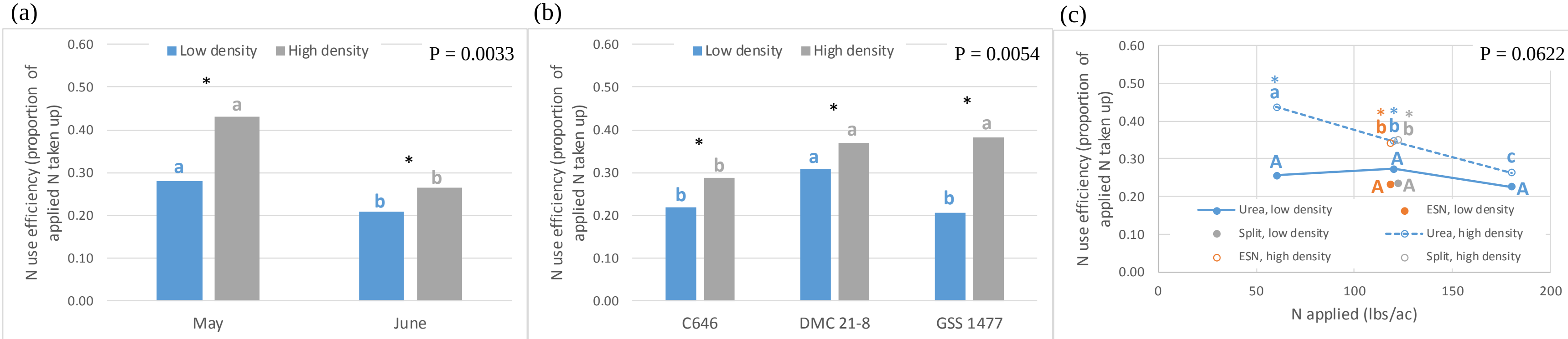

Figure 9. The effects on N use efficiency of the interactions between population density and (a) planting month, (b) hybrid, and (c) N treatment. In (a) and (b), columns that share the same letter in the same color are not significantly different from each other (indicating no effect of planting month or hybrid within a given density class), and asterisks indicate a significant effect of population density within a planting month or hybrid. In (c), uppercase letters are used for low-density plots and lowercase letters are used for high-density plots. Points that share a common letter of the same case (regardless of color) do not have significantly different values.

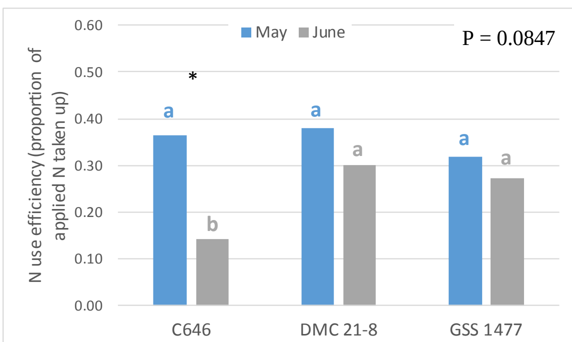

Figure 10. The effect on N use efficiency of the interaction between hybrid and planting month. Columns that share the same letter in the same color are not significantly different from each other (indicating no effect of planting month or hybrid within a given density class), and asterisks indicate a significant effect of population density within a planting month or hybrid.

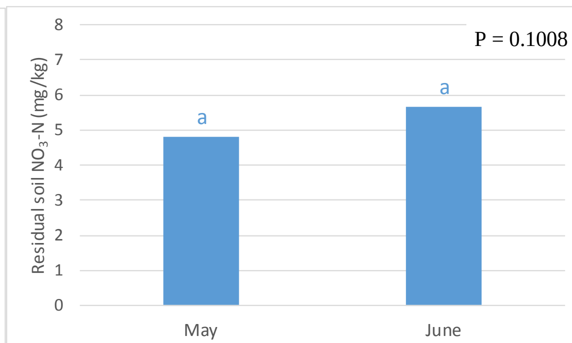

Figure 11. The effect of planting month on end-of-season residual NO_3-N in the top two feet of soil. Columns that share the same letter are not significantly different from each other.

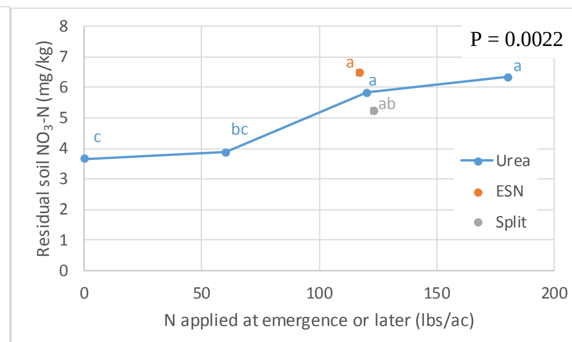

Figure 12. The effect of N treatment on end-of-season residual NO_3-N in the top two feet of soil. Points that share a common letter of the same case (regardless of color) do not have significantly different values.