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Reductions of Wheat Yield and Yield Components and Nitrogen Loss Following Frozen Soil Nitrogen Applications

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Introduction

Most wheat producers in Kentucky apply nitrogen (N) as a split application. The first N increment is applied when wheat plants begin actively growing (green-up) in late winter, which is typically in mid-February between growth stages Feekes 2 to 3. The second N increment typically occurs in March when wheat is between Feekes 5 to 6. Many producers in Kentucky, especially Western Kentucky, have become accustomed to beginning first N applications in late January when the ground is frozen and the wheat is still dormant. This practice allows them to apply N to large acreages of wheat while avoiding rutting and/or compacting fields with large equipment. In most years, the soil will thaw within a few hours or days following N applications, which allows N to infiltrate the soil profile and reduce runoff potential. In 2014 Kentucky had below average temperatures for January and February (UK Ag Weather Center, 2013) resulting in frozen soil until mid-February throughout much of the state and delayed wheat development two to three weeks. In 2014, some producers made early N applications in January to dormant wheat grown on soil that was frozen to a depth of six to nine inches. This study was conducted to estimate grain yield response and N loss and to determine the yield components contributing to changes in grain yields when N was applied to frozen ground.

Materials and Methods

Experimental plots (25 ft^2) were established at two sites in existing wheat that was drilled (no-till) into 7-inch rows at a seeding rate of 168 lbs wheat/A in mid to late October 2013. Both sites were at the University of Kentucky Research and Education Center in Princeton, KY but were situated on two soil types: 1) Crider silt loam soil (Typic Paleudalf) with <1% slope (Pioneer Brand ‘25R29’) and 2) Zanesville silt loam soil (Oxyaquic Fragiudalf) with a 3% slope (Pioneer Brand '25R32'). The experimental design was a randomized complete block with three replications, two initial N rates (40 and 80 lbs N/A as $NaNO_3$), two N application conditions (frozen and thawed soil), and a control (Table 1) that received a single N application (100 lbs N/A as NH_4NO_3 applied on 15 April 2014).

Nitrogen Applications: On 30 January 2014 two N rates (40 and 80 lbs N/A as $NaNO_3$) were applied on frozen soil to dormant wheat (Feekes 2). The first thawed soil N application (40 and 80 lbs N/A as $NaNO_3$) was applied to actively growing wheat (Feekes 3) on 24 February and 13 March for the Crider and Zanesville sites, respectively. On 15 April, the second N (NH_4NO_3) applications were made to supply a total of 100 lbs available N/A for all treatments at Feekes 5 (Table 1).

Soil Nitrate Samples: On 24 February 2014, 12-inch-deep soil samples were collected from the frozen soil treatments and analyzed for soil NO_3^- by cadmium reduction to determine NO_3^- content of soil (Crutchfield and Grove, 2011). For the thawed soil treatments, soil samples (12-inch depth) were collected 11 March for the Crider site and 21 March for the Zanesville soil from plots that received the thawed N application. Soil was analyzed for NO_3^- as described above.

Plant Measurements: Normalized difference vegetation index (NDVI) was measured with a hand-held Greenseeker™ 25 March and 15 April 2014 (Murdock et al. 2013). Plant height and number of heads per foot of row were measured and 100 heads per plot were harvested 16 Jun. The number of spikelets per head was measured for the 100 heads harvested prior to being threshed with a Wintersteiger laboratory thresher. Total number of seed from the 100 heads and hundred kernel weights were measured. To determine grain yield, entire plots were hand harvested 23 June and threshed on 9 July with a Wintersteiger plot combine and total grain was weighed. Grain moisture and test weight were measured with a grain analysis computer (Dickey-John GAC 2100). Yield and test weight were adjusted to 13.5% moisture.

Statistical Analysis: Analyses of variance were conducted for all variables with PROC MIXED in SAS® (version 9.3; SAS Institute, Cary, NC). Nitrogen application timing, N rate, and site were specified as a fixed effects and replication was specified as a random effect. Least squares means were separated at the $P<0.10$ level with *pdmix* (Saxton, 1998).

Results and Discussion

Considerable N loss was expected for the frozen soil N applications because within five days of the frozen soil N application there were 3.01 inches of rain followed by 1.61 inches of snow and rain in the next 15 days. For the frozen soil N applications, soil samples were collected at green-up, which was 25 days after N application. Soil samples were collected from the thawed soil N application treatments following at least one rain event: 15 days after N application for the Crider site and 8 days after N application for the Zanesville site. Soil NO_3^- was greater ($P<0.10$) when N was applied to thawed soils (18.8 ppm) with actively growing wheat plants than when N was applied to frozen soil (6.9 ppm) with dormant plants (Figure 1); the untreated control had the least soil NO_3^- (2.7 ppm) (Figure 1).

When considered in terms of N loss, almost 63% of the N applied to frozen soil was lost. This considerable N loss could be due to runoff, leaching, denitrification, and/or plant uptake. Runoff was thought to be the most likely mode of N loss in this study because N applied to frozen soil could not infiltrate the soil profile. Leaching, denitrification and plant uptake probably did not occur to any great extent because the soil was frozen. Water and N could not move through the soil profile and the daily temperatures were below freezing, which would have resulted in minimal denitrification and no plant uptake. It is possible that the high N loss was also due in part to the form of N chosen for this study. Sodium nitrate ($NaNO_3$) was chosen for this study to allow direct quantification of soil NO_3^-; however it has a higher N loss potential than more conventional fertilizers. The additional time between N application and soil NO_3^- analysis could be an additional reason that soil NO_3^- was less for the frozen soil N treatments. However, the daily temperatures were so low throughout the time from N application to soil

NO_3^- analysis that the soil NO_3^- loss was most likely due to runoff instead of leaching, denitrification or plant uptake (UK Ag Weather Center, 2013).

To compensate for N loss that occurred when the first N application was to frozen soil, additional N was added to the second N application at Feekes 5. The measured 60% loss was an average loss; the range was 49 to 75%. Based upon this information we decided to assume that 50% of the first N application to frozen soil was lost and increased the second application to ensure that all treatments received 100 lbs available N/A (Table 1).

Next, NDVI, plant height, number of heads per foot of row, number of spikelets per head, number of seed per head, 100 kernel weights, grain yield and test weight were measured to estimate the effect of N application timing on wheat growth and yield. When N was applied to thawed soils wheat plants were taller (Figure 2), produced more heads per foot of row (Figure 3), had more spikelets per head (Figure 4), and produced greater grain yields (Figure 5) than was observed when N was applied to frozen soil. Conversely, NDVI, number of seed per head, 100 kernel weights, and test weight did not differ ($P<0.10$) between thawed and frozen soil N treatments (data not shown).

The yield reduction for wheat that received the initial N application to frozen soil was approximately 9% when compared to the treatment that received the initial N application to thawed soil. Reduced yield for the frozen soil treatment was due to fewer heads per foot of row and fewer spikelets per head. There were an additional 5 heads and 0.2 spikelets per head for the thawed soil N treatment than for the frozen soil N treatment. This would result in 373, 370 additional heads (5 x 74, 674 linear feet per acre) and 731,805 additional spikelets (0.2 x 3,659,026 heads per acre) per acre. Assuming that each spikelet produced three seeds, almost 2.2 million additional seeds were produced for the thawed soil N treatment than the frozen soil N treatment. The control treatment that received a single N application produced the least yield: a 15% yield reduction when compared to the thawed soil N treatment and 5% yield reduction when compared to the frozen soil N treatment. This supports previous findings that split N applications increase wheat yield (Murdock et al., 2009). It also suggests that some of the N applied to frozen soil was available to the wheat crop during early developmental stages, thus resulting in greater grain yields than the control treatment.

On the day of harvest, wheat prices were $5.15/bu. When only considering yield loss the penalty for applying N to frozen ground in 2014 was $31/A loss ($5.15/bu x 6 bu/A = $30.90). Many producers noticed chlorotic wheat plants around Feekes 5 and increased the second N rate as described above to assume a 50% loss of the frozen soil N application. Assuming a producer re-applied 30 lbs N/A then this would be about another $15/A economic loss bringing total loss per acre to $46. The total revenue lost by applying a single N application was $46/A ($5.15/bu x 9 bu/A = $46.35). Although the economic losses for the single application and the frozen soil N application were calculated to be equal, these calculations did not take into account fuel, depreciation, or any costs other than direct inputs or returns.

Conclusion

Considerable grain yield reductions and economic losses occurred when N was applied to frozen soil and dormant wheat plants. The yield reductions were a result of reduced number of heads per foot of row and reduced number of spikelets per head. The economic losses resulted from yield reductions and increased input costs, assuming the producer added additional N to compensate for N loss in late winter. This study reiterates the importance of timely N applications to maximize profitable wheat grain yield and the reason that nutrient applications to frozen soils are not recommended by the University of Kentucky nor are they permitted by nutrient management regulations.

References

Crutchfield, J. D. and J. H. Grove. 2011. A new cadmium reduction device for the microplate determination of nitrate in water, soil, plant tissue, and physiological fluids. Journal of AOAC International. 94: 1896-1905.

Murdock, L. W., D. L. Call, J. James, O. Wendroth, P. Needham, and J. W. Hendricks. 2013. Sensor technology for variable-rate nitrogen applications on wheat in Kentucky. University of Kentucky Cooperative Extension Service Publication SR-107.

Murdock, L., J. Grove, and G. Schwab. 2009. Fertilizer management, p. 25-29. In: Lee and Herbek (eds.), 2009. AGR-125: A Comprehensive Guide to Wheat Management in Kentucky. University of Kentucky Cooperative Experiment Service.

Saxton, A.M. 1998. A Macro for converting mean separation output to letter groupings in proc mixed, p. 1243-1246. In: Proc. 23rd SAS Users Group Intl., SAS Institute, Cary, NC.

University of Kentucky Agricultural Weather Center (UK Ag Weather Center). 2013. Kentucky Climate Data. Lexington, KY. http//wwwagwx.ca.uky.edu/ (accessed 15 September 2014).

Table 1. Nitrogen (N) rates, total N applied and estimated N available to soft red winter wheat in 2014 following frozen and thawed soil N applications, Princeton, KY.

N Application Soil Condition	First Application	Second Application	Applied	Estimated Available
	N Rate (lbs N/A)		Total N (lbs N/A) †	
Frozen Soil	40	80	120	100
Frozen Soil	80	60	140	100
Thawed Soil	40	60	100	100
Thawed Soil	80	20	100	100
Control	0	100	100	100

†Average N loss was assumed to be 50% for the first N application on the frozen soil and 0% for the first N application on the thawed soil.

Figure 1. Mean soil nitrate for soils collected to 12-inch-depths for treatments that received the first nitrogen (N) application when the soil was frozen, thawed and for an untreated control that did not receive N, Princeton, KY, 2014. Means labelled with different letters are significantly different (*t* test, $P<0.10$).

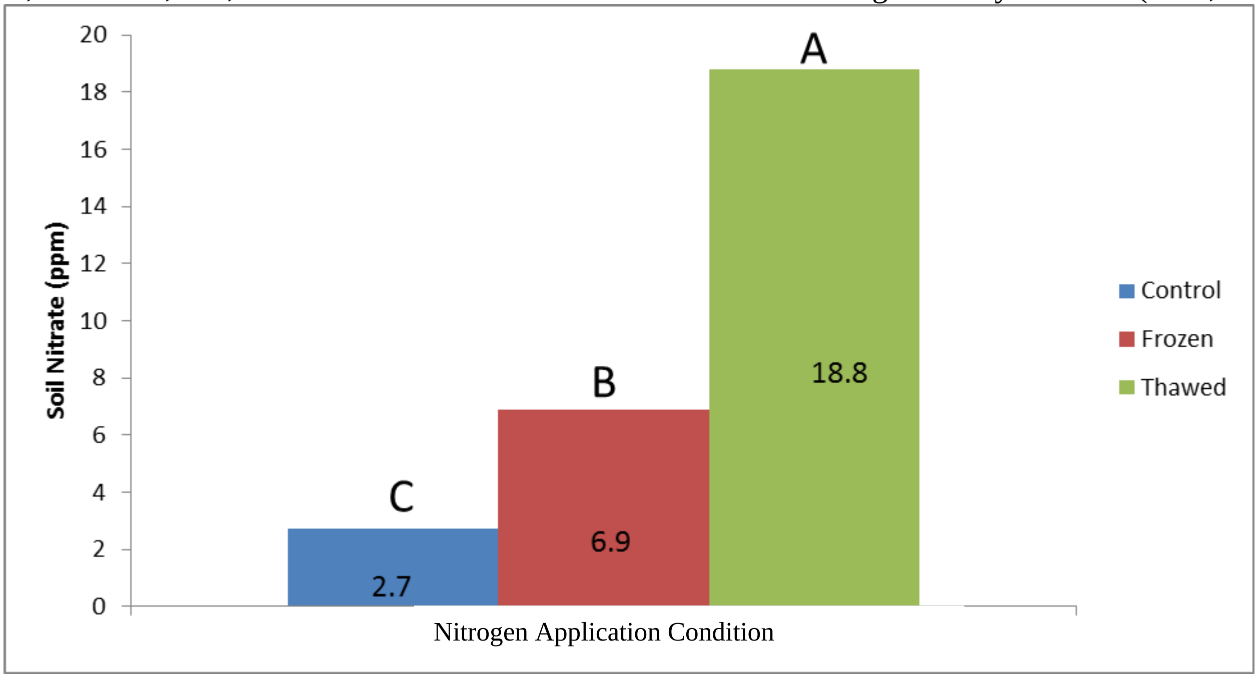


Figure 2. Mean plant height of soft red winter wheat that received the first nitrogen (N) application when soil was frozen or thawed and for the control that received a single N application (100 lbs N/A as NH_4NO_3) at Feekes 5, Princeton, KY, 2014. The first N application (40 or 80 lbs N/A) was applied as $NaNO_3$ at Feekes 2 for the frozen soil treatment and Feekes 3 for the thawed soil treatment. The second N application was applied at Feekes 5 as NH_4NO_3 to bring total available N to 100 lbs N/A; 50% N loss was assumed for the first frozen soil N application. Means labelled with different letters are significantly different (*t* test, $P<0.10$).

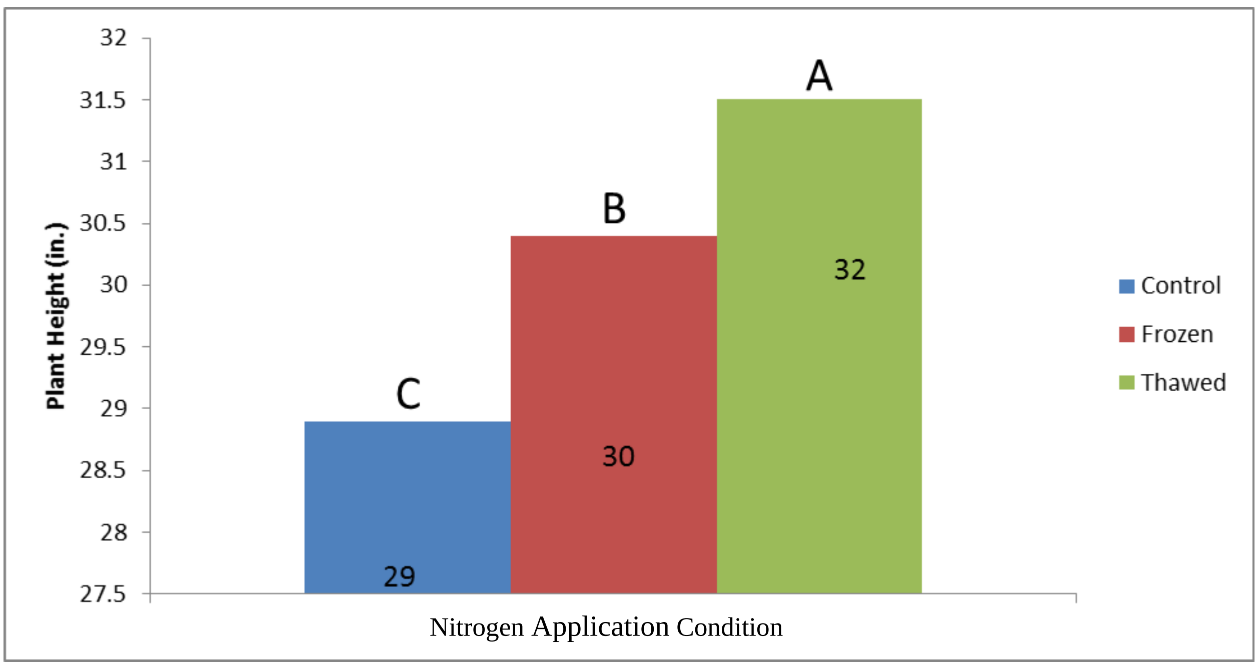


Figure 3. Mean number of heads per foot of row for soft red winter wheat that received the first nitrogen (N) application when soil was frozen or thawed and for the control that received a single N application (100 lbs N/A as NH_4NO_3) at Feekes 5, Princeton, KY, 2014. The first N application (40 or 80 lbs N/A) was applied as $NaNO_3$ at Feekes 2 for the frozen soil treatment and Feekes 3 for the thawed soil treatment. The second N application was applied at Feekes 5 as NH_4NO_3 to bring total available N to 100 lbs N/A; 50% N loss was assumed for the first frozen soil N application. Means labelled with different letters are significantly different (*t* test, P<0.10).

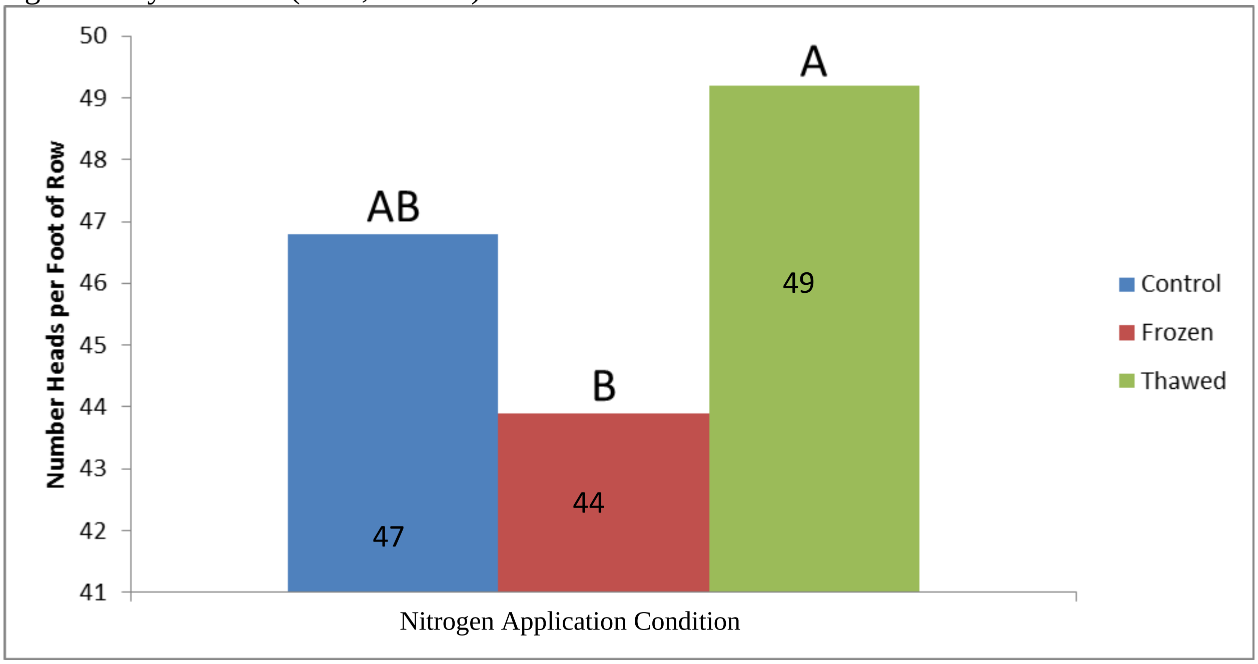


Figure 4. Mean number of soft red winter wheat spikelets per head for treatments received the first nitrogen (N) application when soil was frozen or thawed and for the control that received a single N application (100 lbs N/A as NH_4NO_3) at Feekes 5, Princeton, KY, 2014. The first N application (40 or 80 lbs N/A) was applied as $NaNO_3$ at Feekes 2 for the frozen soil treatment and Feekes 3 for the thawed soil treatment. The second N application was applied at Feekes 5 as NH_4NO_3 to bring total available N to 100 lbs N/A; 50% N loss was assumed for the first frozen soil N application. Means labelled with different letters are significantly different (*t* test, $P<0.10$).

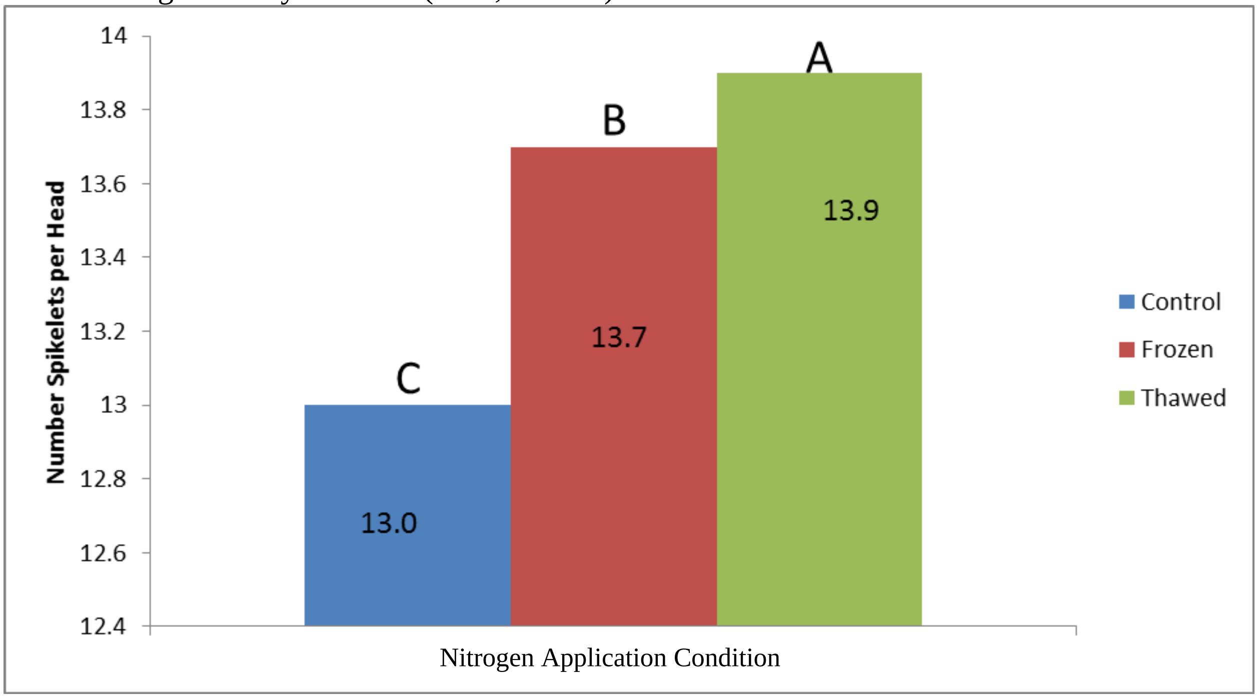
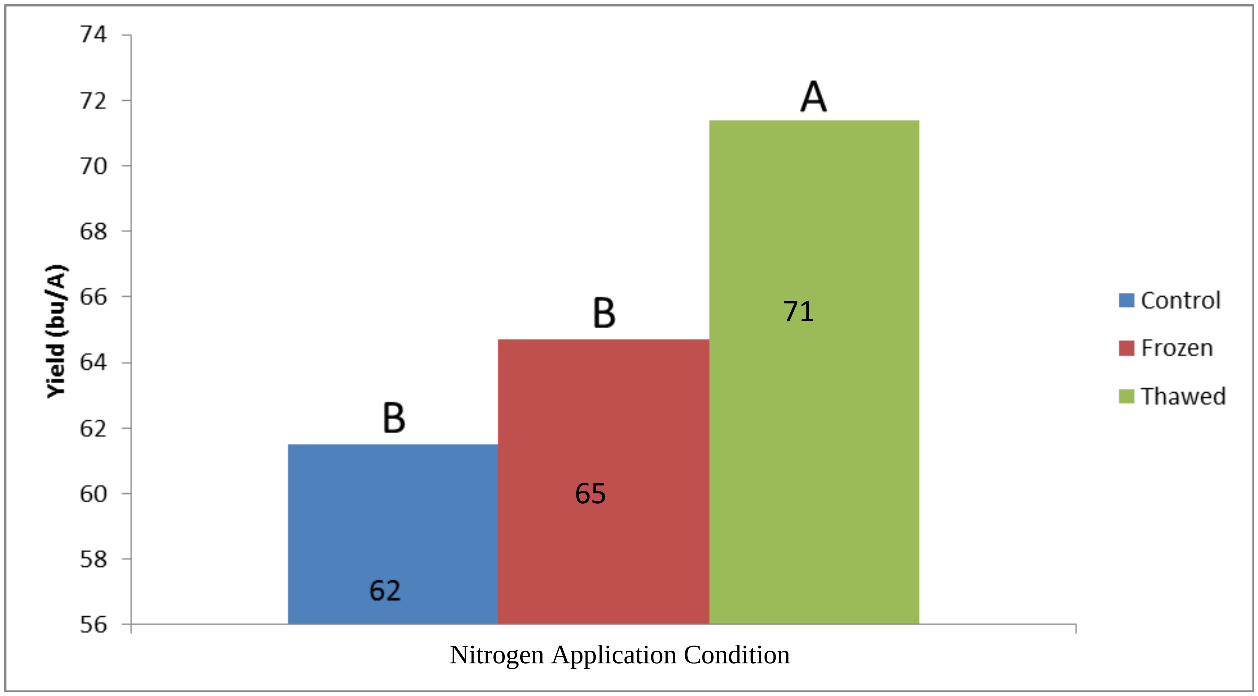


Figure 5. Mean grain yield of soft red winter wheat that received the first nitrogen (N) application when soil was frozen or thawed and for the control that received a single N application (100 lbs N/A as NH_4NO_3) at Feekes 5, Princeton, KY, 2014. The first N application (40 or 80 lbs N/A) was applied as $NaNO_3$ at Feekes 2 for the frozen soil treatment and Feekes 3 for the thawed soil treatment. The second N application was applied at Feekes 5 as NH_4NO_3 to bring total available N to 100 lbs N/A; 50% N loss was assumed for the first frozen soil N application. Means labelled with different letters are significantly different (*t* test, P<0.10).



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