Minnesota Department of Agriculture
Pesticide & Fertilizer Management
FINAL REPORT
FOR THE PERIOD: FEBRUARY 15, 2022 – MARCH 31, 2023

PROJECT NUMBER:	R2022-29, SWIFT Agreement #211350, MDA P.O. #3000042251, University of Minnesota Award #CON000000096767
PROJECT DESCRIPTION:	Advancing Continuous Corn with Mid-Season Application of Nitrogen and Sulfur
REPORT DUE DATE:	April 30, 2023

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1) GOALS AND OBJECTIVES OBTAINED

a) ***Collect 0- to 6-inch soil samples and analyze for organic matter, pH, phosphorus, and potassium.*** Soil samples were collected from both locations in the spring prior to field operations and were analyzed.

b) ***Apply preplant fertilizers.*** Preplant fertilizers were applied at both locations.

c) ***Plant corn and apply herbicides.*** At both locations, corn was planted, followed by preemergence and postemergence herbicide applications.

d) ***Measure corn plant population.*** Corn plant population was measured from all plots at both locations.

e) ***Build a single one-row 360 Y-DROP® applicator for application of V14 fertilizer treatments at both locations.*** This objective was fully completed by early July.

f) ***At V14 prior to the V14 fertilizer applications, collect corn leaf samples, dry and grind them, and then analyze them for nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, iron, boron, copper, manganese, and zinc.*** Corn leaf samples were collected at the V14 corn stage from both locations just prior to the V14 fertilizer applications. The samples were then dried, ground, and analyzed for nitrogen (N), sulfur (S), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), boron (B), copper (Cu), manganese (Mn), and zinc (Zn).

g) ***Apply V14 fertilizer treatments.*** The V14 fertilizer treatments were applied at Lamberton, MN on July 22, 2022 and at Waseca, MN on July 19, 2022.

h) ***After corn has reached physiological maturity, collect whole-plant samples of corn, separate them into grain, cob, and stover fractions, and dry and weigh them.*** This objective was fully completed in early October.

i) ***Harvest plots with a combine to measure grain yield and moisture content.*** This objective was fully completed in mid-October, 2022.

j) ***Analyze the corn grain, cob, and stover samples that were collected at physiological maturity for nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, iron, boron, copper, manganese, and zinc.*** This objective was fully completed. The samples were analyzed in March 2023.

k) ***Calculate corn whole-plant dry matter yield and uptake of nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, iron, boron, copper, manganese, and zinc.*** This objective was fully completed. The results are shared below in this report.

l) ***Measure dry kernel weight and calculate kernels per square foot.*** This objective was fully completed. The results are shared below in this report.

m) ***Calculate corn recovery efficiency, physiological use efficiency, and agronomic use efficiency of nitrogen and sulfur fertilizers.*** This objective was fully completed. The results are shared below in this report.

n) ***Conduct an economic analysis that includes cost, revenue, and net return for the different treatments.*** This objective was fully completed. The results are shared below in this report.

o) ***Share results from this project with farmers and agricultural professionals through Extension activities.*** This objective was fully completed. The results from this project were shared with farmers and agricultural professionals through presentations at the University of Minnesota Extension Institute for Agricultural Professionals Research Update Meetings at Lamberton, MN on January 5, 2023, at Morris, MN on January 10, 2023, and at Willmar, MN on January 11, 2023, at the University of Minnesota Southern Research and Outreach Center Winter Crops Day on January 12, 2023, and at the University of Minnesota Extension Rice and Steele Counties Crops Day at Faribault, MN on March 7, 2023.

2) ACTIVITIES PERFORMED

a) This project involved field experiments on Normania loam soil at the University of Minnesota Southwest Research and Outreach Center near Lamberton, MN and on Nicollet clay loam soil at the University of Minnesota Southern Research and Outreach Center near Waseca, MN during the 2022 growing season. The previous crop at both locations was corn, which had been stalk chopped and disk-ripped in the fall.

To accomplish the goal/objective "*collect 0- to 6-inch soil samples and analyze for organic matter, pH, phosphorus, and potassium*", soil samples were collected from the 0- to 6-inch depth in April 2022 prior to preplant fertilization. One composite soil sample based on 10 cores was collected from each of the four replications at each location. The soil samples were dried in a forced-air oven at 95°F, crushed, sieved, and analyzed by the University of Minnesota Research Analytical

Laboratory for organic matter (loss on ignition), pH (water), Bray-phosphorus 1, exchangeable K, and sulfate-sulfur. The results of these analyses are in Table 1.

Table 1. Baseline soil-test levels from the 0- to 6-inch soil layer at Lamberton, MN and Waseca, MN in April 2022.[1]

Variable	Lamberton	Waseca
Organic matter, %	4.6	5.7
pH (water)	5.4	6.6
Bray-phosphorus 1, ppm	59	24
Exchangeable potassium, ppm	257	187
Sulfate-sulfur, ppm	18	10

[1] Values are the average across four replications at each location.

The experiment at each location contained 30 treatments (three corn hybrids × two planting rates × five fertilizer treatments) in a randomized complete block design with four replications (Table 2). The plots were four rows (30-inch) wide by 30 feet long. The three corn hybrids were DKC50-87RIB, DKC54-64RIB, and DKC58-64RIB, with relative maturity (RM) ratings of 100, 104, and 108, respectively. These hybrids reflect the range of hybrid RM that local farmers use, and they have tolerance to herbicides and resistance to above-and below-ground insect pests. The two planting rates were 34,000 and 38,000 seeds/acre, which represent low and high planting rates for high-yield environments. The five fertilizer treatments included different strategies for managing N and S, along with non-N- and non-S-fertilized controls to enable calculation of corn recovery efficiency, physiological use efficiency, and agronomic use efficiency of N and S fertilizers. The five fertilizer treatments are listed below. The total N rate of 200 lb N/acre and the base rate of 25 lb S/acre represent standard farmer practices.

1. Preplant N and S: 200 lb N/acre + 25 lb S/acre preplant

2. Split N and preplant S: 160 lb N/acre + 25 lb S/acre preplant, and 40 lb N/acre at V14

3. Split N, preplant S, and additional S: 160 lb N/acre + 25 lb S/acre preplant, and 40 lb N/acre + 10 lb S /acre at V14

4. Preplant N and no S: 200 lb N/acre preplant

5. No N and preplant S: 25 lb S/acre preplant

Table 2. Description of the 30 treatments in the field experiments at Lamberton, MN and Waseca, MN in 2022.

Treatment	Hybrid	Planting rate (seeds/acre)	Nitrogen (N) and sulfur (S) fertilization
1	DKC50-87RIB	34,000	Preplant N and S
2	DKC50-87RIB	34,000	Split N and preplant S
3	DKC50-87RIB	34,000	Split N, preplant S, and additional S
4	DKC50-87RIB	34,000	Preplant N and no S
5	DKC50-87RIB	34,000	No N and preplant S
6	DKC50-87RIB	38,000	Preplant N and S
7	DKC50-87RIB	38,000	Split N and preplant S
8	DKC50-87RIB	38,000	Split N, preplant S, and additional S
9	DKC50-87RIB	38,000	Preplant N and no S
10	DKC50-87RIB	38,000	No N and preplant S
11	DKC54-64RIB	34,000	Preplant N and S
12	DKC54-64RIB	34,000	Split N and preplant S
13	DKC54-64RIB	34,000	Split N, preplant S, and additional S
14	DKC54-64RIB	34,000	Preplant N and no S
15	DKC54-64RIB	34,000	No N and preplant S
16	DKC54-64RIB	38,000	Preplant N and S
17	DKC54-64RIB	38,000	Split N and preplant S
18	DKC54-64RIB	38,000	Split N, preplant S, and additional S
19	DKC54-64RIB	38,000	Preplant N and no S
20	DKC54-64RIB	38,000	No N and preplant S
21	DKC58-64RIB	34,000	Preplant N and S
22	DKC58-64RIB	34,000	Split N and preplant S
23	DKC58-64RIB	34,000	Split N, preplant S, and additional S
24	DKC58-64RIB	34,000	Preplant N and no S
25	DKC58-64RIB	34,000	No N and preplant S
26	DKC58-64RIB	38,000	Preplant N and S
27	DKC58-64RIB	38,000	Split N and preplant S
28	DKC58-64RIB	38,000	Split N, preplant S, and additional S
29	DKC58-64RIB	38,000	Preplant N and no S
30	DKC58-64RIB	38,000	No N and preplant S

b) To accomplish the goal/objective "*apply preplant fertilizers*", preplant phosphorus (P), potassium (K), N, and S fertilizers were broadcast prior to preplant tillage in 2022. Triple super phosphate (0-46-0) and potash (0-0-60) were applied preplant to the entire experimental area at each location based on soil-test P and K levels and University of Minnesota Extension guidelines for a 260 bushel/acre yield. Preplant N and S were applied using urea (46-0-0) and pelletized gypsum (0-0-0-17S), respectively for the various treatments according to Table 2.

Preplant applications of N and S were made using urea (46-0-0) and pelletized gypsum (0-0-0-17S), respectively for the various treatments according to Table 2. Pelletized gypsum was used as the S source for the preplant fertilizer applications rather than ammonium sulfate (21-0-0-24S) because ammonium sulfate contains N and would have resulted in some N being applied to the "no N and preplant S" treatment. This would have invalidated the calculations of corn recovery efficiency, physiological use efficiency, and agronomic use efficiency of N and S fertilizers because of a potential soil priming effect resulting from N being applied to the non-N-fertilized treatment. An alternative option would have been to apply ammonium sulfate to the first four fertilizer treatments and to apply pelletized gypsum to the non-N-fertilized treatment, but then the S source would have been confounded with treatment and that would have also invalidated the calculations due to differences in S release between the two fertilizer sources. For these reasons, pelletized gypsum was used as the S source for all preplant fertilizer applications.

c) To accomplish the goal/objective "*plant corn and apply herbicides*", corn was planted according to Table 2 on May 16, 2022 at Waseca, MN and on May 23, 2022 at Lamberton, MN using a four-row precision plot planter equipped with RTK GPS. At both locations, a preemergence herbicide was applied soon after planting, followed by a postemergence herbicide application after weed emergence.

d) To accomplish the goal/objective "*measure corn plant population*", corn plant population was measured at the four-leaf collar corn stage by counting all plants within the center two rows of each plot.

Photos 1 and 2. Leaf striping at the five-leaf collar corn stage due to S deficiency in the treatment with preplant N and no S (the non-S-fertilized control) at Waseca, MN (left photo) in 2022. In comparison, the right photo shows corn with no S deficiency symptoms in the treatment with preplant N and S.

e) The goal/objective "*build a single one-row 360 Y-DROP® applicator for application of V14 fertilizer treatments at both locations*" was fully completed by early July 2022. The applicator is shown below.

Photo 3. One-row 360 Y-DROP® applicator for application of V14 fertilizer treatments in small plots at Lamberton, MN and Waseca, MN.

f) Another goal/objective that was accomplished was "*at V14 prior to the V14 fertilizer applications, collect corn leaf samples, dry and grind them, and then analyze them for nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, iron, boron, copper, manganese, and zinc*". This was done by collecting corn leaf samples at the V14 corn stage from both locations in 2022 just prior to the V14 fertilizer applications. The samples were then dried, ground, and analyzed for N, S, P, K, Ca, Mg, Fe, B, Cu, Mn, and Zn. For most nutrients at both locations, corn leaf nutrient levels at the V14 stage just prior to the V14 fertilizer applications were significantly affected by fertilizer treatment and corn hybrid, but not by corn planting rate. Additionally, it was rare for corn leaf nutrient levels to be significantly affected by interactions between fertilizer treatment, corn hybrid, or corn planting rate. Therefore, results are presented by fertilizer treatment (Tables 3 and 4) and hybrid (Tables 5 and 6).

Corn leaf nutrient levels at the V14 stage just prior to the V14 fertilizer applications differed among the five fertilizer treatments (Tables 3 and 4). As with corn hybrid RM, the results differed by nutrient and location. Some key findings are as follows. At both locations, leaf nutrient levels were almost always lower for the control treatment that received "no N and preplant N" compared to the other treatments at both locations. In several other instances, especially at Lamberton where it was drier from planting until the time of leaf sampling, nutrient levels were also lower in the control treatment that received "preplant N and no S". Additionally, nutrient levels were frequently lower for treatments involving split application of N at Lamberton where it was drier during, but not at Waseca where it was wetter.

The three corn hybrids of differing RM differed in their leaf nutrient levels at the V14 stage just prior to the V14 fertilizer applications (Tables 5 and 6). The results differed by nutrient and location, but there were a few consistencies. First, leaf S, B, and Cu concentrations were lower in the 108 RM hybrid than the 100 and 104 RM hybrids at both locations. Second, leaf P concentration was greater in the 104 RM hybrid than in the 100 and 108 RM hybrids at both locations. Third, leaf Zn concentration in the 100 RM hybrid was greater than that in the 104 and 108 RM hybrids at both locations.

Table 3. Effect of fertilizer treatment on corn leaf nutrient levels at the V14 corn stage at Lamberton, MN in 2022, just prior to the V14 fertilizer applications. Means are averaged over all three hybrids and both planting rates. Within a row, means followed by the same letter are not significantly different at the 0.05 probability level.

Variable	Preplant N and S	Split N and preplant S	Split N, preplant S, and additional S	Preplant N and no S	No N and preplant S
Nitrogen, %	2.87 a	2.67 b	2.72 b	2.67 b	2.34 c
Sulfur, %	0.172 a	0.166 a	0.171 a	0.153 b	0.153 b
Phosphorus, %	0.317 a	0.308 a	0.310 a	0.312 a	0.273 b
Potassium, %	2.01 a	1.99 b	1.99 b	2.02 a	1.92 b
Calcium, %	0.337 ab	0.326 bc	0.353 a	0.305 d	0.321 cd
Magnesium, %	0.230 bc	0.231 bc	0.245 a	0.220 c	0.236 ab
Iron, ppm	107.2 a	89.1 a	96.2 a	91.7 a	88.3 a
Boron, ppm	15.9 a	15.4 a	14.8 a	16.0 a	12.0 b
Copper, ppm	9.51 a	8.95 bc	9.43 ab	8.57 c	7.90 d
Manganese, ppm	73.0 a	64.3 b	66.2 b	67.8 b	44.0 c
Zinc, ppm	21.1 a	20.8 a	20.4 a	20.6 a	17.8 b

Table 4. Effect of fertilizer treatment on corn leaf nutrient levels at the V14 corn stage at Waseca, MN in 2022, just prior to the V14 fertilizer applications. Means are averaged over all three hybrids and both planting rates. Within a row, means followed by the same letter are not significantly different at the 0.05 probability level.

Variable	Preplant N and S	Split N and preplant S	Split N, preplant S, and additional S	Preplant N and no S	No N and preplant S
Nitrogen, %	2.98 a	2.94 a	3.00 a	3.06 a	2.10 b
Sulfur, %	0.193 a	0.190 ab	0.189 ab	0.183 b	0.153 c
Phosphorus, %	0.318 b	0.312 b	0.309 b	0.332 a	0.267 c
Potassium, %	2.03 a	2.05 a	2.04 a	2.06 a	2.09 a
Calcium, %	0.400 ab	0.411 a	0.400 ab	0.387 b	0.379 b
Magnesium, %	0.228 a	0.228 a	0.225 a	0.231 a	0.208 b
Iron, ppm	83.3 a	81.9 a	82.9 a	85.8 a	66.1 b
Boron, ppm	9.19 ab	8.64 b	8.86 ab	9.48 a	5.29 c
Copper, ppm	9.44 a	9.08 ab	8.93 b	9.43 a	6.84 c
Manganese, ppm	40.6 ab	37.2 b	37.3 b	42.7 a	27.8 c
Zinc, ppm	19.9 a	20.1 a	19.7 a	20.5 a	13.7 b

Table 5. Effect of hybrid relative maturity (RM) on corn leaf nutrient levels at the V14 corn stage at Lamberton, MN in 2022, just prior to the V14 fertilizer applications. Means are averaged over both planting rates and all five fertilizer treatments. Within a row, means followed by the same letter are not significantly different at the 0.05 probability level.

Variable	100 RM	104 RM	108 RM
Nitrogen, %	2.60 a	2.72 a	2.64 a
Sulfur, %	0.165 a	0.168 a	0.156 b
Phosphorus, %	0.294 b	0.324 a	0.294 b
Potassium, %	2.04 a	1.96 b	1.95 b
Calcium, %	0.308 b	0.333 a	0.344 a
Magnesium, %	0.213 b	0.238 a	0.246 a
Iron, ppm	83.0 a	98.6 a	101.9 a
Boron, ppm	15.5 a	15.5 a	13.5 b
Copper, ppm	8.96 ab	9.19 a	8.46 b
Manganese, ppm	62.2 b	61.0 b	66.0 a
Zinc, ppm	22.0 a	19.0 b	19.3 b

Table 6. Effect of hybrid relative maturity (RM) on corn leaf nutrient levels at the V14 corn stage at Waseca, MN in 2022, just prior to the V14 fertilizer applications. Means are averaged over both planting rates and all five fertilizer treatments. Within a row, means followed by the same letter are not significantly different at the 0.05 probability level.

Variable	100 RM	104 RM	108 RM
Nitrogen, %	2.75 b	2.88 a	2.82 a
Sulfur, %	0.183 a	0.188 a	0.173 b
Phosphorus, %	0.305 b	0.326 a	0.291 c
Potassium, %	2.10 a	2.06 ab	2.01 b
Calcium, %	0.367 c	0.394 b	0.425 a
Magnesium, %	0.218 b	0.220 b	0.235 a
Iron, ppm	78.0 c	82.5 a	79.5 b
Boron, ppm	8.71 a	9.00 a	7.17 b
Copper, ppm	8.85 ab	9.15 a	8.23 b
Manganese, ppm	36.5 a	37.6 a	37.3 a
Zinc, ppm	20.2 a	18.3 b	17.9 b

g) To accomplish the goal/objective "*Apply V14 fertilizer treatments*", the V14 fertilizer treatments were applied using the one-row 360 Y-DROP® applicator at Lamberton, MN on July 22, 2022 and at Waseca, MN on July 19, 2022. The N and S that was applied at V14 was applied as urea ammonium nitrate (28-0-0) and ammonium thiosulfate (12-0-0-26S) placed on the soil near both sides of corn rows using the 360 Y-DROP® system. A urease inhibitor was used with both V14 applications.

Photos 4 and 5. Application of the V14 fertilizer treatments using the one-row 360 Y-DROP® applicator.

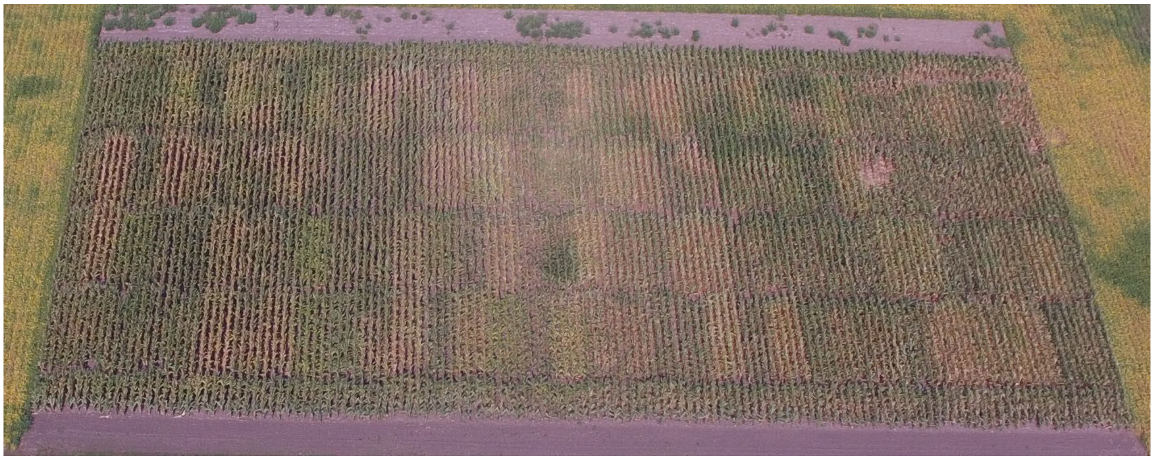

Photo 6. Aerial view of the experiment at Lamberton, MN on September 4, 2022. There is a 15-foot border of corn on the top (north) and bottom (south) edges of the experiment, along with four rows (10 feet) of border of corn on the left (west) and right (east) edges of the experiment. Differences in senescence among the plots at this location with limited rainfall are due to differences in the treatments (hybrids differing in relative maturity, planting rate, and fertilizer treatment).

Rainfall amount and distribution differed greatly between the two locations in 2022 (Table 7). At Waseca, MN, rainfall was abundant and relatively evenly distributed throughout the growing season, with a total of 20.1 inches during May through September. However, Lamberton, MN received just 13.0 inches of rainfall during the same period, with just 5.7 inches of rainfall during June through August. As a result, corn yield was high at Waseca, MN (maximum yield of 241 bushels/acre, averaged across hybrids and planting rates) but exceptionally low at Lamberton, MN (maximum yield of 157 bushels/acre, averaged across hybrids and planting rates).

Table 7. Monthly total rainfall during the 2022 growing season at Lamberton, MN and Waseca, MN.

	Lamberton, MN	**Waseca, MN**
------ Month ------	--------- rainfall (inches) ---------	
May	3.5	4.7
June	1.1	4.4
July	1.8	4.6
August	2.8	5.6
September	3.8	0.8
Total (May–September)	13.0	20.1

h) To accomplish the goal/objective "*after corn has reached physiological maturity, collect whole-plant samples of corn, separate them into grain, cob, and stover fractions, and dry and weigh them*", whole-plant corn samples were collected from each plot at the R6 growth stage (physiological maturity) in early October 2022. Ears were separated from the rest of the plant (stover). Ears were dried, weighed, and shelled, after which grain and cobs were weighed separately. Stover was weighed, chipped, sub-sampled in the field, with sub-samples weighed wet and again after drying. These data were used to calculate whole plant dry matter yield.

Photos 7 and 8. Whole plant samples with ears separated at Lamberton, MN (Photo 7). Chipping and sub-sampling stover in the field at Lamberton, MN (Photo 8).

i) To accomplish the goal/objective "*harvest plots with a combine to measure grain yield and moisture content*", plots were end-trimmed and harvested using a plot combine in mid-October 2022. Grain yield was adjusted to 15% moisture content. There were no significant interactions among fertilizer treatment, hybrid, and planting rate for corn grain yield or grain moisture content at harvest for either location, other than a significant interaction between fertilizer treatment and hybrid at Waseca. Therefore, the results are shown separately for the main effects of fertilizer treatment, hybrid, and planting rate, and as averages over all levels of the other variables (Tables 8–13).

At Lamberton, corn grain yield was relatively low and not significantly different among fertilizer treatments (Table 8). At Waseca, corn grain yield averaged 41% less for the treatment that did not receive N fertilizer compared to the other four fertilizer treatments (Table 11). Corn grain yield was not significantly different among hybrids at Lamberton (Table 9), but at Waseca it averaged 4% less for the 104 RM hybrid compared to the 100 and 108 RM hybrids (Table 12). There were no significant differences between planting rates for corn grain yield at either location (Tables 10 and 13).

At Lamberton, corn grain moisture content at harvest was not significantly different among fertilizer treatments (Table 8). At Waseca, corn grain moisture content at harvest was highest for the treatment with no N fertilizer, intermediate for the treatment with no S fertilizer, and least for the remaining treatments (Table 11). At Lamberton, corn grain moisture content at harvest was 16.6% for the 108 RM hybrid, which was 0.6 percentage points higher than that for the 100 and 104 RM hybrids (Table 9). At Waseca, corn grain moisture content at harvest was highest for the 108 RM hybrid, intermediate for the 104 RM hybrid, and least for the 100 RM hybrid (Table 12).

There were no significant differences in grain moisture content at harvest between the two planting rates at either location (Tables 10 and 13).

j) To accomplish the goal/objective "*analyze the corn grain, cob, and stover samples that were collected at physiological maturity for nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, iron, boron, copper, manganese, and zinc*", the samples were dried immediately after sampling, ground, and later analyzed for N, S, P, K, Ca, Mg, Fe, B, Cu, Mn, and Zn. These nutrient concentration data were used to calculate whole-plant uptake of these nutrients, as described below.

k) To accomplish the goal/objective "*calculate corn whole-plant dry matter yield and uptake of nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, iron, boron, copper, manganese, and zinc*", corn whole plant dry matter yield was calculated as the sum of dry matter yield for grain, cob, and stover. Whole-plant nutrient uptake was calculated as the sum of the products of dry matter yield and nutrient concentration for grain, cob, and stover. There were no significant interactions among fertilizer treatment, hybrid, and planting rate for corn whole plant dry matter yield at physiological maturity for either location. Therefore, the results are shown as averages for the main effects of fertilizer treatment, hybrid, and planting rate (Tables 8–13).

At Lamberton, corn whole plant dry matter yield was relatively low and not significantly different among fertilizer treatments (Table 8). At Waseca, corn whole plant dry matter yield averaged 35% less for the treatment that did not receive N fertilizer compared to the other four fertilizer treatments (Table 11). Corn whole plant dry matter yield was not significantly different among hybrids at Lamberton (Table 9), but at Waseca it averaged 3% less for the 104 RM hybrid compared to the 100 and 108 RM hybrids (Table 12). There were no significant differences between planting rates for corn whole plant dry matter yield at either location (Tables 10 and 13).

There were few significant interactions of meaningful importance among fertilizer treatment, hybrid, and planting rate for corn aboveground nutrient uptake at physiological maturity at either location. Therefore, the results for corn aboveground nutrient uptake are shown as averages for the main effects of fertilizer treatment, hybrid, and planting (Tables 8–13).

At Lamberton, corn aboveground uptake of N at physiological maturity was not significantly different among the four fertilizer treatments with N applied, but greatest uptake of S occurred only in the treatments involving "preplant N and S" and "split N, preplant S, and additional S" (Table 8). For all other nutrients except copper at Lamberton, either the "preplant N and S" or "preplant N and no S" resulted in the highest level of nutrient uptake. There were no significant differences in corn uptake of Zn at maturity among fertilizer treatments at Lamberton.

At Lamberton, corn nutrient uptake at physiological maturity was greatest for the 108 RM hybrid for N, K, Ca, and Mg, and with the 104 RM hybrid for S and B, but it was not significantly different among hybrids for Fe, Mn, Cu, and Zn (Table 9). Averaged across fertilizer treatments and hybrids, corn aboveground nutrient uptake at maturity was not significantly different between the two planting rates for any measured nutrient except Mn, for which the planting rate of 34,000 seeds/acre resulted in greater uptake of Mn than 38,000 seeds/acre (Table 10).

At Waseca, which had much higher corn grain yield and whole plant dry matter yield at maturity, corn aboveground uptake of N at maturity was greatest for the treatments involving "preplant N and S", "split N, preplant S, and additional S", and "preplant N and no S" (Table 11). Corn uptake of S at maturity at Waseca was reduced only for the treatments involving no N or no S. For Ca, Mg, B, and Fe, corn uptake of these nutrients at maturity at Waseca was greatest for the treatments involving "preplant N and S", "split N, preplant S, and additional S", and "preplant N and no S". There were no significant differences in corn uptake of Zn at maturity among fertilizer treatments at Waseca.

Corn nutrient uptake at maturity at Waseca did not differ among the three hybrids for N, S, P, Fe, Mn, Cu, and Zn, but greatest uptake of K and B occurred with the 104 and 108 RM hybrids, greatest uptake of Ca occurred only for the 108 RM hybrid, and greatest uptake of Mg occurred with the 100 and 108 RM hybrids (Table 12). Corn aboveground nutrient uptake at maturity at Waseca was not significantly different between the two planting rates for any measured nutrient (Table 13).

l) To accomplish the goal/objective "*measure dry kernel weight and calculate kernels per square foot*", a grain sample from each plot was collected during combine harvesting. These grain samples were oven-dried until constant mass, then 300 kernels of each sample were counted and weighed. The 300-kernel weights were then divided by 300 to obtain weight per kernel, which is one of the two primary yield components of corn. The other primary yield component of corn is kernels per square foot. This was calculated by adjusting grain yield to 0% moisture and dividing it by kernel weight. The results for kernel weight and kernels per square foot are shown in Tables 8–13.

   At Lamberton, where corn grain yield was not significantly different among fertilizer treatments, hybrids, or planting rates (Tables 8–10), weight per kernel was not significantly different among the five fertilizer treatments, but it was greater for the 104 RM hybrid than the 100 and 108 RM hybrids (Table 9), and it was also greater for the planting rate of 34,000 seeds/acre compared to 38,000 seeds/acre (Table 10). Kernels per square foot at Lamberton was not affected by fertilizer treatment (Table 8) or planting rate (Table 10), but it was reduced with the 104 RM hybrid (Table 9).

   At Waseca, weight per kernel and kernels per square foot were reduced only with the fertilizer treatment involving "no N and preplant S" (Table 11). Additionally, weight per kernel at Waseca was greatest with the 104 RM hybrid and the planting rate of 34,000 seeds/acre, while kernels per square foot were greatest with either the 100 RM or 104 hybrids and with the planting rate of 38,000 seeds/acre (Tables 12 and 13).

m) Another goal/objective that was accomplished was "*calculate corn recovery efficiency, physiological use efficiency, and agronomic use efficiency of nitrogen and sulfur fertilizers*". These parameters were calculated as follows for each combination of hybrid and planting rate:

   i) <u>Recovery efficiency of N and S fertilizers</u> = [(corn aboveground nutrient uptake in the treatment with fertilization – corn aboveground nutrient uptake in the corresponding control treatment without fertilization) / (fertilizer rate in the treatment with fertilization)]

   ii) <u>Physiological use efficiency of N and S fertilizers</u> = [(corn grain yield in the treatment with fertilization – corn grain yield in the corresponding treatment without fertilization) / (corn aboveground nutrient uptake in the treatment with fertilization – corn aboveground nutrient uptake in the corresponding treatment without fertilization)]

   iii) <u>Agronomic use efficiency of N and S fertilizers</u> = [(corn grain yield in the treatment with fertilization – corn grain yield in the corresponding treatment without fertilization) / (fertilizer rate in the treatment with fertilization)]

   Among the first three fertilizer treatments, which are those of practical importance, the three calculated indices of corn use efficiency of N and S fertilizers were not significantly different at either location (Tables 8 and 11). At Lamberton, recovery efficiency of fertilizer N was lower with the 108 RM hybrid, and recovery efficiency of fertilizer S was lower with the 104 and 108 RM hybrids (Table 9) and with the planting rate of 38,000 seeds/acre (Table 10). At Waseca, the three calculated indices of corn use efficiency of N and S fertilizers were not significantly different among the three hybrids (Table 12) or between the two planting rates (Table 13).

n) Another goal/objective that was accomplished was "*conduct an economic analysis that includes cost, revenue, and net return for the different treatments*". For this, the cost was calculated for each treatment, and included only those costs that differed among treatments (i.e., seed amount, N and S fertilizers, urease inhibitor for the V14 fertilizer applications, and the custom application cost for the V14 fertilizer application). Costs of production were based on quotes from local suppliers. The cost of seed for all three hybrids was set at $3.53/1,000 seeds; therefore, the cost of the treatment with 38,000 seeds/acre was $14/acre greater than that of the treatment with 34,000 seeds/acre. For the fertilizer treatments, the cost of urea (46-0-0) was set at $0.68/lb N, the cost of pelletized gypsum (0-0-0-17S) was set at $0.68lb S, the cost of urea ammonium nitrate (liquid 28-0-0) was set at $0.76/lb N, the cost of ammonium thiosulfate (liquid 12-0-0-26S) was set at $0.2076/lb of product ($0.80/lb S), the cost of a urease inhibitor for the V14 fertilizer applications was set at $7.00/acre, and the V14 custom fertilizer application was set at $10.35/acre based on the Iowa State University Extension custom rate survey. The cost of the experimental treatments are shown in Tables 8–13.

Revenue was calculated by plot as the product of corn grain yield and corn selling price (set at $6.50 per bushel), minus drying costs for grain harvest moisture above 15% (set at $0.035 per percentage point of moisture per bushel). Partial net return was calculated for each plot as revenue minus treatment cost. Data for revenue and partial net return were analyzed statistically and the results are shown in Tables 8–13.

At Lamberton, where corn grain yield and revenue were not significantly different among fertilizer treatments, hybrids, or planting rates, partial net return was greatest with the treatment involving "no N and preplant S", and it was also $46/acre greater with the planting rate of 34,000 seeds/acre than 38,000 seeds/acre (Tables 8–10). At Waseca, revenue and partial net return were greatest for all fertilizer treatments except the one involving "no N and preplant S" (Table 11). Revenue and partial net return at Waseca were greater for the 100 and 108 RM hybrids than the 104 RM hybrid (Table 12), but they were not affected by planting rate (Table 13).

o) To accomplish the goal/objective "*share results from this project with farmers and agricultural professionals through Extension activities*", the results from this project were shared with farmers and agricultural professionals through presentations at the University of Minnesota Extension Institute for Agricultural Professionals Research Update Meetings at Lamberton, MN on January 5, 2023, at Morris, MN on January 10, 2023, and at Willmar, MN on January 11, 2023, at the University of Minnesota Southern Research and Outreach Center Winter Crops Day on January 12, 2023, and at the University of Minnesota Extension Rice and Steele Counties Crops Day at Faribault, MN on March 7, 2023.

Table 8. Corn yield, grain moisture at harvest, grain yield components, economic parameters, aboveground nutrient uptake at maturity (R6 stage), and indices of N and S fertilizer use efficiency as affected by fertilizer treatment at Lamberton, MN in 2022, averaged across three hybrids and two planting rates.

Variable	Preplant N and S	Split N and preplant S	Split N, preplant S, and additional S	Preplant N and no S	No N and preplant S
Grain yield (bu/acre at 15%)	164 a [1]	160 a	157 a	163 a	162 a
Grain moisture at harvest (%)	15.7 a	15.6 a	15.9 a	15.6 a	15.5 a
Weight per kernel (mg)	295 a	288 a	290 a	290 a	284 a
Kernels per square foot	220 a	221 a	215 a	222 a	226 a
Treatment cost ($/acre) [2]	273	294	298	256	137
Revenue ($/acre)	1,060 a	1,037 a	1,013 a	1,053 a	1,050 a
Partial net return ($/acre)	780 b	737 bc	708 c	790 b	906 a
Whole plant dry matter yield at R6 (tons/acre)	7.98 a	7.91 a	7.79 a	7.96 a	7.51 a
Aboveground N uptake at R6 (lb N/acre)	162 a	154 a	157 a	158 a	111 b
Recovery efficiency of fertilizer N (lb increase in aboveground N uptake at R6 per lb N applied)	0.255 a	0.216 a	0.230 a	0.236 a	---
Physiological N use efficiency (bushels gained per 1-lb increase in aboveground N uptake at R6)	-0.123 a	-0.627 a	0.308 a	-1.55 a	---
Agronomic N use efficiency (bushels gained per lb N applied)	-0.0003 a	0.0289 a	-0.0221 a	0.0049 a	---
Aboveground S uptake at R6 (lb S/acre)	11.3 a	10.4 b	11.1 ab	9.0 c	8.9 c
Recovery efficiency of fertilizer S (lb increase in aboveground S uptake at R6 per lb S applied)	0.0941 a	0.0580 a	0.0620 a	---	-0.0032 b
Physiological S use efficiency (bushels gained per 1-lb increase in aboveground S uptake at R6)	-0.23 a	-1.69 a	-2.43 a	---	-0.32 a
Agronomic S use efficiency (bushels gained per lb S applied)	-0.0126 a	-0.0533 a	0.0633 a	---	0.0712 a
Aboveground P uptake at R6 (lb P/acre)	29.2 a	27.9 a	26.8 a	28.0 a	21.8 b
Aboveground K uptake at R6 (lb K/acre)	108 a	99 b	99 b	104 a	81 c
Aboveground Ca uptake at R6 (lb Ca/acre)	24.8 a	21.3 cd	22.0 bc	24.1 ab	19.2 d
Aboveground Mg uptake at R6 (lb Mg/acre)	28.6 a	26.1 b	26.1 b	27.0 ab	22.4 c
Aboveground B uptake at R6 (lb B/acre)	4.94 a	4.25 b	4.21 b	4.83 a	4.04 b
Aboveground Fe uptake at R6 (lb Fe/acre)	98 ab	76 c	80 bc	110 a	84 bc
Aboveground Mn uptake at R6 (lb Mn/acre)	45.7 a	38.0 b	36.6 b	43.9 a	28.9 c
Aboveground Cu uptake at R6 (lb Cu/acre)	2.71 a	2.26 b	2.23 b	2.13 b	1.58 c
Aboveground Zn uptake at R6 (lb Zn/acre)	23.5 a	21.8 ab	21.8 ab	23.5 a	20.0 b

[1] Within a row, values followed by the same letter are not significantly different at the 0.05 probability level.

[2] Includes only those costs that differed among treatments.

Table 9. Corn yield, grain moisture at harvest, grain yield components, economic parameters, aboveground nutrient uptake at maturity (R6 stage), and indices of N and S fertilizer use efficiency as affected by corn hybrid relative maturity (RM) at Lamberton, MN in 2022, averaged across five fertilizer treatments and two planting rates.

Variable	100 RM	104 RM	108 RM
Grain yield (bu/acre at 15%)	161 a [1]	159 a	164 a
Grain moisture at harvest (%)	15.5 b	15.5 b	16.1 a
Weight per kernel (mg)	273 c	311 a	285 b
Kernels per square foot	233 a	202 b	228 a
Treatment cost ($/acre) [2]	259	259	259
Revenue ($/acre)	1042 a	1029 a	1057 a
Partial net return ($/acre)	783 a	770 a	799 a
Whole plant dry matter yield at R6 (tons/acre)	7.82 a	7.62 a	8.06 a
Aboveground N uptake at R6 (lb N/acre)	138 b	147 b	159 a
Recovery efficiency of fertilizer N (lb increase in aboveground N uptake at R6 per lb N applied)	0.244 ab	0.278 a	0.180 b
Physiological N use efficiency (bushels gained per 1-lb increase in aboveground N uptake at R6)	-0.11 a	-0.13 a	-1.26 a
Agronomic N use efficiency (bushels gained per lb N applied)	-0.0377 a	0.0393 a	0.0029 a
Aboveground S uptake at R6 (lb S/acre)	9.67 b	10.2 ab	10.5 a
Recovery efficiency of fertilizer S (lb increase in aboveground S uptake at R6 per lb S applied)	0.0909 a	0.0322 b	0.0352 b
Physiological S use efficiency (bushels gained per 1-lb increase in aboveground S uptake at R6)	-4.07 a	-3.44 a	4.00 a
Agronomic S use efficiency (bushels gained per lb S applied)	-0.287 a	0.065 a	0.273 a
Aboveground P uptake at R6 (lb P/acre)	25.4 a	27.7 a	27.2 a
Aboveground K uptake at R6 (lb K/acre)	88 b	93 b	114 a
Aboveground Ca uptake at R6 (lb Ca/acre)	20.7 b	18.6 c	27.6 a
Aboveground Mg uptake at R6 (lb Mg/acre)	25.6 b	24.4 b	28.2 a
Aboveground B uptake at R6 (lb B/acre)	3.85 b	4.70 a	4.81 a
Aboveground Fe uptake at R6 (lb Fe/acre)	83.6 a	89.3 a	95.6 a
Aboveground Mn uptake at R6 (lb Mn/acre)	38.9 a	38.6 a	38.5 a
Aboveground Cu uptake at R6 (lb Cu/acre)	2.19 a	2.21 a	2.15 a
Aboveground Zn uptake at R6 (lb Zn/acre)	21.1 a	22.1 a	22.9 a

[1] Within a row, values followed by the same letter are not significantly different at the 0.05 probability level.

[2] Includes only those costs that differed among treatments.

Table 10. Corn yield, grain moisture at harvest, grain yield components, economic parameters, aboveground nutrient uptake at maturity (R6 stage), and indices of N and S fertilizer use efficiency as affected by corn planting rate at Lamberton, MN in 2022, averaged across five fertilizer treatments and three corn hybrids.

Variable	34,000 seeds/acre	38,000 seeds/acre
Grain yield (bu/acre at 15%)	163 a [1]	159 a
Grain moisture at harvest (%)	15.6 a	15.8 a
Weight per kernel (mg)	294 a	284 b
Kernels per square foot	220 a	221 a
Treatment cost ($/acre) [2]	252	266
Revenue ($/acre)	1,059 a	1,027 a
Partial net return ($/acre)	807 a	761 b
Whole plant dry matter yield at R6 (tons/acre)	7.92 a	7.74 a
Aboveground N uptake at R6 (lb N/acre)	148 a	147 a
Recovery efficiency of fertilizer N (lb increase in aboveground N uptake at R6 per lb N applied)	0.261 a	0.207 a
Physiological N use efficiency (bushels gained per 1-lb increase in aboveground N uptake at R6)	-0.741 a	-0.255 a
Agronomic N use efficiency (bushels gained per lb N applied)	0.0239 a	-0.0182 a
Aboveground S uptake at R6 (lb S/acre)	10.3 a	9.9 a
Recovery efficiency of fertilizer S (lb increase in aboveground S uptake at R6 per lb S applied)	0.0712 a	0.0343 b
Physiological S use efficiency (bushels gained per 1-lb increase in aboveground S uptake at R6)	-2.13 a	-0.20 a
Agronomic S use efficiency (bushels gained per lb S applied)	0.128 a	-0.09 a
Aboveground P uptake at R6 (lb P/acre)	27.5 a	26.0 a
Aboveground K uptake at R6 (lb K/acre)	98.4 a	97.9 a
Aboveground Ca uptake at R6 (lb Ca/acre)	22.3 a	23.3 a
Aboveground Mg uptake at R6 (lb Mg/acre)	25.8 a	26.2 a
Aboveground B uptake at R6 (lb B/acre)	4.53 a	4.38 a
Aboveground Fe uptake at R6 (lb Fe/acre)	91.8 a	87.2 a
Aboveground Mn uptake at R6 (lb Mn/acre)	40.4 a	36.9 b
Aboveground Cu uptake at R6 (lb Cu/acre)	2.20 a	2.17 a
Aboveground Zn uptake at R6 (lb Zn/acre)	22.6 a	21.4 a

[1] Within a row, values followed by the same letter are not significantly different at the 0.05 probability level.

[2] Includes only those costs that differed among treatments.

Table 11. Corn yield, grain moisture at harvest, grain yield components, economic parameters, aboveground nutrient uptake at maturity (R6 stage), and indices of N and S fertilizer use efficiency as affected by fertilizer treatment at Waseca, MN in 2022, averaged across three hybrids and two planting rates.

Variable	Preplant N and S	Split N and preplant S	Split N, preplant S, and additional S	Preplant N and no S	No N and preplant S
Grain yield (bu/acre at 15%)	238 a [1]	236 a	241 a	236 a	140 b
Grain moisture at harvest (%)	17.6 bc	17.4 c	17.4 c	17.8 b	18.5 a
Weight per kernel (mg)	324 a	326 a	326 a	328 a	288 b
Kernels per square foot	291 a	287 a	292 a	284 a	193 b
Treatment cost ($/acre) [2]	273	294	298	256	137
Revenue ($/acre)	1,528 a	1,514 a	1,545 a	1,508 a	896 b
Partial net return ($/acre)	1,248 a	1,213 a	1,240 a	1,245 a	752 b
Whole plant dry matter yield at R6 (tons/acre)	10.7 a	10.3 a	10.5 a	10.6 a	6.9 b
Aboveground N uptake at R6 (lb N/acre)	210 ab	201 b	204 ab	213 a	111 c
Recovery efficiency of fertilizer N (lb increase in aboveground N uptake at R6 per lb N applied)	0.500 a	0.451 a	0.461 a	0.513 a	---
Physiological N use efficiency (bushels gained per 1-lb increase in aboveground N uptake at R6)	0.99 a	1.15 a	1.12 a	0.97 a	---
Agronomic N use efficiency (bushels gained per lb N applied)	0.493 a	0.509 a	0.477 a	0.455 a	---
Aboveground S uptake at R6 (lb S/acre)	16.2 a	16.0 a	16.5 a	14.9 b	10.3 c
Recovery efficiency of fertilizer S (lb increase in aboveground S uptake at R6 per lb S applied)	0.049 a	0.042 a	0.048 a	---	-0.184 b
Physiological S use efficiency (bushels gained per 1-lb increase in aboveground S uptake at R6)	-2.38 a	1.62 a	-1.92 a	---	26.2 a
Agronomic S use efficiency (bushels gained per lb S applied)	0.03 a	0.13 a	0.43 a	---	-3.82 b
Aboveground P uptake at R6 (lb P/acre)	38.4 a	40.1 a	39.4 a	39.9 a	28.8 b
Aboveground K uptake at R6 (lb K/acre)	132 a	131 a	132 a	134 a	99 b
Aboveground Ca uptake at R6 (lb Ca/acre)	30.3 ab	28.3 b	29.1 ab	30.8 a	18.1 c
Aboveground Mg uptake at R6 (lb Mg/acre)	30.9 a	28.6 b	30.3 a	31.5 a	18.5 c
Aboveground B uptake at R6 (lb B/acre)	5.98 ab	5.74 b	5.76 ab	6.21 a	3.91 c
Aboveground Fe uptake at R6 (lb Fe/acre)	73.3 ab	65.9 b	69.0 ab	74.3 a	56.7 c
Aboveground Mn uptake at R6 (lb Mn/acre)	31.3 a	29.0 a	26.8 a	31.1 a	16.0 b
Aboveground Cu uptake at R6 (lb Cu/acre)	4.31 a	4.39 a	4.32 a	4.23 a	1.58 b
Aboveground Zn uptake at R6 (lb Zn/acre)	27.9 a	27.6 a	28.3 a	29.3 a	27.0 a

[1] Within a row, values followed by the same letter are not significantly different at the 0.05 probability level.

[2] Includes only those costs that differed among treatments.

Table 12. Corn yield, grain moisture at harvest, grain yield components, economic parameters, aboveground nutrient uptake at maturity (R6 stage), and indices of N and S fertilizer use efficiency as affected by corn hybrid relative maturity (RM) at Waseca, MN in 2022, averaged across five fertilizer treatments and two planting rates.

Variable	100 RM	104 RM	108 RM
Grain yield (bu/acre at 15%)	220 a [1]	212 b	222 a
Grain moisture at harvest (%)	16.5 c	18.0 b	18.7 a
Weight per kernel (mg)	312 b	336 a	308 b
Kernels per square foot	277 a	248 b	283 a
Treatment cost ($/acre) [2]	259	259	259
Revenue ($/acre)	1,419 a	1,358 b	1,418 a
Partial net return ($/acre)	1,160 a	1,100 b	1,159 a
Whole plant dry matter yield at R6 (tons/acre)	9.77 ab	9.58 b	10.05 a
Aboveground N uptake at R6 (lb N/acre)	186 a	189 a	189 a
Recovery efficiency of fertilizer N (lb increase in aboveground N uptake at R6 per lb N applied)	0.452 a	0.500 a	0.493 a
Physiological N use efficiency (bushels gained per 1-lb increase in aboveground N uptake at R6)	1.04 a	1.07 a	1.07 a
Agronomic N use efficiency (bushels gained per lb N applied)	0.437 a	0.500 a	0.514 a
Aboveground S uptake at R6 (lb S/acre)	15.1 a	14.6 a	14.7 a
Recovery efficiency of fertilizer S (lb increase in aboveground S uptake at R6 per lb S applied)	-0.0108 a	-0.0033 a	0.0025 a
Physiological S use efficiency (bushels gained per 1-lb increase in aboveground S uptake at R6)	3.19 a	9.02 a	5.44 a
Agronomic S use efficiency (bushels gained per lb S applied)	-0.750 a	-0.487 a	-1.184 a
Aboveground P uptake at R6 (lb P/acre)	36.7 a	37.7 a	37.5 a
Aboveground K uptake at R6 (lb K/acre)	120 b	127 a	130 a
Aboveground Ca uptake at R6 (lb Ca/acre)	26.9 b	24.1 c	30.9 a
Aboveground Mg uptake at R6 (lb Mg/acre)	28.9 a	26.2 b	28.7 a
Aboveground B uptake at R6 (lb B/acre)	4.93 b	5.81 a	5.83 a
Aboveground Fe uptake at R6 (lb Fe/acre)	66.4 a	68.7 a	68.4 a
Aboveground Mn uptake at R6 (lb Mn/acre)	27.2 a	28.7 a	24.6 a
Aboveground Cu uptake at R6 (lb Cu/acre)	3.93 a	3.86 a	3.51 a
Aboveground Zn uptake at R6 (lb Zn/acre)	28.2 a	27.4 a	28.5 a

1 Within a row, values followed by the same letter are not significantly different at the 0.05 probability level.

2 Includes only those costs that differed among treatments.

Table 13. Corn yield, grain moisture at harvest, grain yield components, economic parameters, aboveground nutrient uptake at maturity (R6 stage), and indices of N and S fertilizer use efficiency as affected by corn planting rate at Waseca, MN in 2022, averaged across five fertilizer treatments and three corn hybrids.

Variable	34,000 seeds/acre	38,000 seeds/acre
Grain yield (bu/acre at 15%)	217 a [1]	219 a
Grain moisture at harvest (%)	17.7 a	17.8 a
Weight per kernel (mg)	322 a	315 b
Kernels per square foot	265 b	274 a
Treatment cost ($/acre) [2]	252	266
Revenue ($/acre)	1,392 a	1,404 a
Partial net return ($/acre)	1,141 a	1,138 a
Whole plant dry matter yield at R6 (tons/acre)	9.67 a	9.93 a
Aboveground N uptake at R6 (lb N/acre)	187 a	189 a
Recovery efficiency of fertilizer N (lb increase in aboveground N uptake at R6 per lb N applied)	0.480 a	0.483 a
Physiological N use efficiency (bushels gained per 1-lb increase in aboveground N uptake at R6)	1.03 a	1.08 a
Agronomic N use efficiency (bushels gained per lb N applied)	0.467 a	0.500 a
Aboveground S uptake at R6 (lb S/acre)	14.7 a	14.9 a
Recovery efficiency of fertilizer S (lb increase in aboveground S uptake at R6 per lb S applied)	-0.0251 a	0.002 a
Physiological S use efficiency (bushels gained per 1-lb increase in aboveground S uptake at R6)	3.93 a	7.85 a
Agronomic S use efficiency (bushels gained per lb S applied)	-0.821 a	-0.793 a
Aboveground P uptake at R6 (lb P/acre)	37.4 a	37.2 a
Aboveground K uptake at R6 (lb K/acre)	125 a	126 a
Aboveground Ca uptake at R6 (lb Ca/acre)	27.2 a	27.5 a
Aboveground Mg uptake at R6 (lb Mg/acre)	27.6 a	28.3 a
Aboveground B uptake at R6 (lb B/acre)	5.52 a	5.51 a
Aboveground Fe uptake at R6 (lb Fe/acre)	67.6 a	68.1 a
Aboveground Mn uptake at R6 (lb Mn/acre)	26.4 a	27.2 a
Aboveground Cu uptake at R6 (lb Cu/acre)	3.73 a	3.80 a
Aboveground Zn uptake at R6 (lb Zn/acre)	27.5 a	28.5 a

[1] Includes only those costs that differed among treatments.

[2] Within a row, values followed by the same letter are not significantly different at the 0.05 probability level.