# Phosphorus by Nitrogen Rate Trial

**David Mettler**[1], **Mark Bloomquist**[2], and **John A. Lamb**[3],
[1]Research Agronomist, [2]Research Director, SMBSC, Renville, MN
[3]Professor Emeritus University of Minnesota, St. Paul, MN

Nitrogen management is a priority to produce high-quality sugar beets. However, many other nutrients also play a role in plant growth. It is important to understand how the availability of other major nutrients such as phosphorus may be impacted by varying levels of nitrogen.

***Research Objective***

- Provide phosphorus and nitrogen fertilizer guidelines for sugar beet production in the Southern Minnesota Beet Sugar Cooperative growing area.

***Methodology***

These trials were conducted as a 3 x 5 factorial with four replications from 2023-2025 in fields near Renville, Minnesota. Soil samples were taken in the fall prior to treatment application (Table 1). The applied nitrogen fertilizer rates were 0, 45, and 115lbs N/A in 2024 and 2025. In 2023 the applied nitrogen rate was 0, 70, and 140lbs N/A as that site had a lower soil residual. The phosphorus fertilizer rates were 0, 15, 30, 45, and 60lbs $P_2O_5$/A. The phosphorus and nitrogen treatments were applied broadcast in the spring and incorporated using a small field cultivator. The nitrogen source was urea (46-0-0), and the phosphorus source was triple super phosphate (0-46-0). Standard practices were used to keep the site weed and disease free. The center two rows of each six-row plot were harvested using a six-row defoliator and a two-row research harvester. The beets harvested from the center two rows were weighed on the harvester and two samples of those beets were used for a quality analysis at the SMBSC tare lab. The data was analyzed for significance using SAS GLM version 9.4. In 2024 and 2025 a starter fertilizer treatment of a mix of 3 gal 6-24-6 plus 3 gal of water applied at a rate of 6 gal/A was added to compare against the broadcast $P_2O_5$. Three gallons of 6-24-6/A delivers 2 lbs N/A, 8 lbs $P_2O_5$ /A, and 2 lbs $K_2O$ /A.

**Table 1.** Soil test results and important dates for all three trial locations.

| | 2023 | 2024 | 2025 |
|---|---|---|---|
| Fall Soil nitrate-N 0-4 ft. (lb N/A) | 33 | 55 | 85 |
| Spring Soil nitrate-N 0-4 ft. (lb N/A) | 62 | 67 | 76 |
| Olsen P 0-6 in. (ppm) | 3 | 4 | 5 |
| K 0-6 in. (ppm) | 224 | 136 | 128 |
| pH 0-6 in. (unitless) | 8.0 | 8.1 | 7.7 |
| Organic matter 0-6 in. (%) | 5.3 | 5.8 | 4.9 |
| Previous Crop | Soybean | Soybean | Field Corn |
| Planting Date | May 4th | April 23rd | April 30th |
| Harvest Date | September 18th | October 3rd | September 25th |

***Results***

The application of phosphorus and nitrogen did not have an interaction on yield or quality. The application of phosphorus did not impact any quality parameters and only increased yield with the first rate of additional $P_2O_5$ (Tables 5, 6, and 7). The use of starter (3 gal/A of 6-24-6) alone had similar root yield to all other phosphorus treatments at the same nitrogen rate (Tables 8 and 9). The application of nitrogen had a negative impact on quality in 2023 and 2025 but no impact in 2024 (Tables 2, 3, and 4). The yield response to nitrogen was linear in 2024 but plateaued in 2023 and 2025 after 100 and 130lbs/A of total nitrogen (soil test plus fertilizer N) respectively.

***Conclusions***

Phosphorus having a significant impact on root yield was not surprising as the soil sample results indicated very low soil test levels of phosphorus (Table 1). What was surprising was that increasing the rate of phosphorus only improved root yield up to 15 – 30lbs of additional phosphate/A with no further increase in root yield after those rates (Table 5, 6, and 7). The response to additional nitrogen over the control was expected and consistent with previous studies when conducted on sites with low residual nitrogen (Tables 2, 3, and 4). After sufficiency levels were met there does not appear to be any benefit to increasing the rate of phosphorus if the rate of

nitrogen is increased. However, if the phosphorus needs are not met, root yield will be reduced even with high levels of nitrogen. These trials stress the importance of soil sampling and understanding the underlying nutrient levels of a field prior to planting.

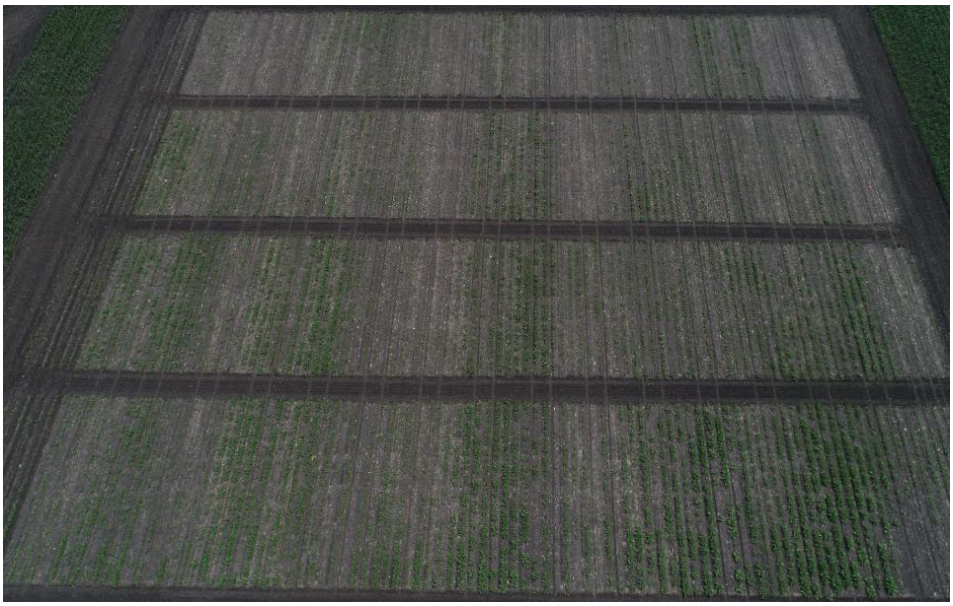

**Figure 1.** Drone images from 2023 trial on June 15th and July 20th showing reduced foliage in plots that were deficient in phosphorus, nitrogen, or both.

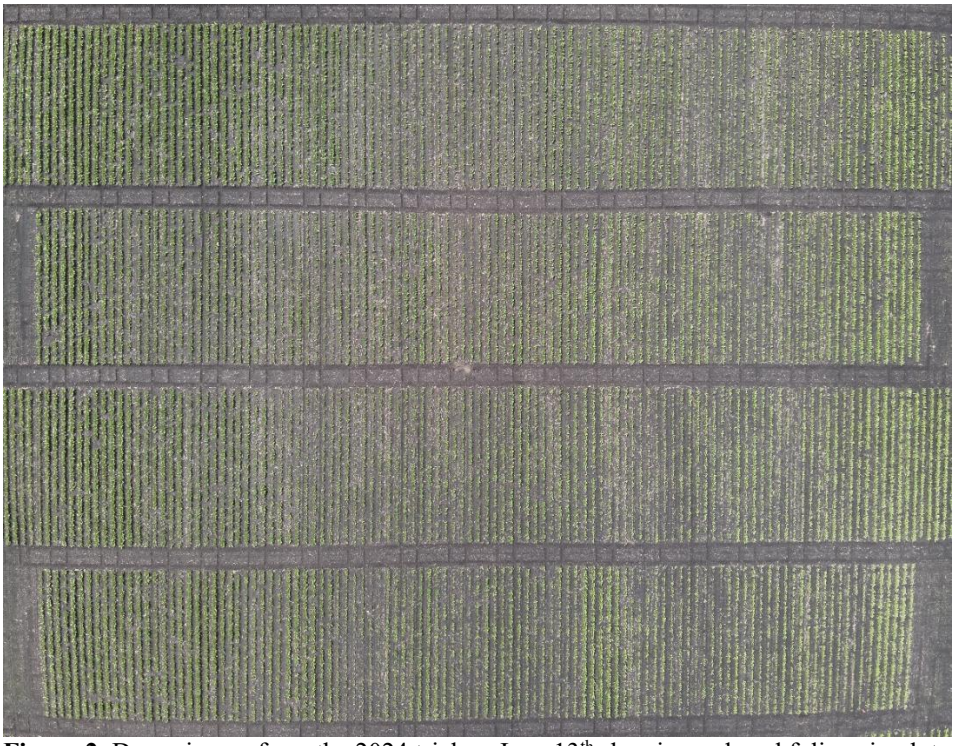

**Figure 2.** Drone image from the 2024 trial on June 13th showing reduced foliage in plots that were deficient in phosphorus, nitrogen, or both.

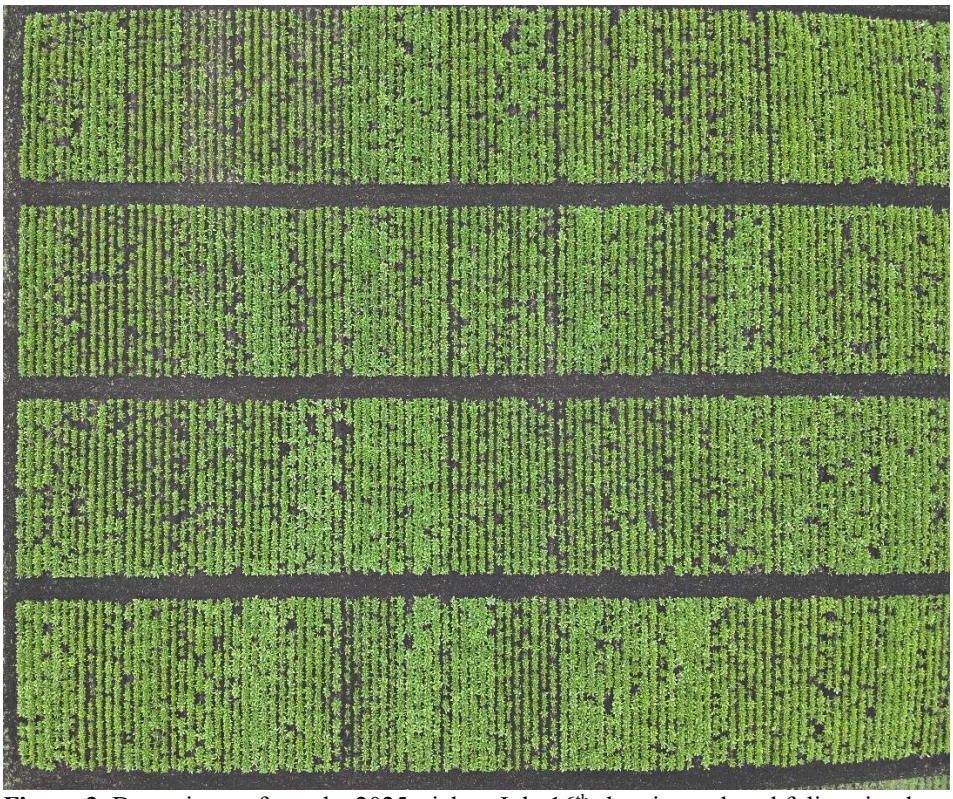

**Figure 3.** Drone image from the 2025 trial on July 16th showing reduced foliage in plots that were deficient in phosphorus, nitrogen, or both.

**Table 2.** 2023 The effect of fertilizer N on yield and quality averaged across $P_2O_5$ rates.

| N Rate (lbs per acre) | Total N (lbs per acre) | Sugar | Tons per Acre | Percent Extractable Sugar | Extractable Sugar per Ton (lbs.) | Extractable Sugar per Acre (lbs.) | Percent Purity |
|---|---|---|---|---|---|---|---|
| 0 | 33 | 17.2 a | 28.0 b | 14.4 a | 288.8 a | 8101.9 b | 90.1 |
| 70 | 102 | 17.2 a | 32.1 a | 14.4 a | 288.1 a | 9269.8 a | 89.9 |
| 140 | 173 | 16.9 b | 31.7 a | 14.1 b | 283.0 b | 8976.7 a | 90.0 |
| | Mean | 17.1 | 30.6 | 14.3 | 286.6 | 8782.8 | 90.0 |
| | CV% | 1.7 | 10.6 | 1.7 | 1.7 | 11.0 | 0.4 |
| | Pr>F | 0.0011 | 0.0004 | 0.0008 | 0.0008 | 0.0012 | 0.2451 |
| | lsd (0.05) | 0.18 | 2.07 | 0.16 | 3.11 | 614.40 | ns |

**Table 3.** 2024 The effect of fertilizer N on yield and quality averaged across P2O5 rates.

| N Rate (lbs per acre) | Total N (lbs per acre) | Sugar | Tons per Acre | Percent Extractable Sugar | Extractable Sugar per Ton (lbs.) | Extractable Sugar per Acre (lbs.) | Percent Purity |
|---|---|---|---|---|---|---|---|
| 0 | 55 | 17.5 | 31.4 c | 14.9 | 298.0 | 9343.3 c | 90.9 |
| 45 | 100 | 17.5 | 35.5 b | 14.8 | 296.3 | 10518.1 b | 90.8 |
| 115 | 170 | 17.4 | 37.6 a | 14.8 | 295.0 | 11081.5 a | 90.6 |
| | Mean | 17.5 | 34.8 | 14.8 | 296.4 | 10314.3 | 90.8 |
| | CV% | 1.5 | 6.8 | 1.8 | 1.8 | 6.1 | 0.6 |
| | Pr>F | 0.5429 | <.0001 | 0.2402 | 0.2216 | <.0001 | 0.121 |
| | lsd (0.05) | ns | 1.5 | ns | ns | 403.8 | ns |

**Table 4.** 2025 The effect of fertilizer N on yield and quality averaged across P2O5 rates.

| N Rate (lbs per acre) | Total N (lbs per acre) | Sugar | Tons per Acre | Percent Extractable Sugar | Extractable Sugar per Ton (lbs.) | Extractable Sugar per Acre (lbs.) | Percent Purity |
|---|---|---|---|---|---|---|---|
| 0 | 85 | 15.1 a | 26.7 b | 12.9 a | 258.6 a | 6906.1 b | 92.0 |
| 45 | 130 | 15.3 a | 29.3 a | 12.9 a | 259.2 a | 7589.9 a | 91.5 |
| 115 | 200 | 14.9 b | 30.9 a | 12.7 b | 254.5 b | 7871.7 a | 91.8 |
| | Mean | 15.1 | 29.0 | 12.9 | 257.4 | 7455.9 | 91.8 |
| | CV% | 1.8 | 9.3 | 1.9 | 1.9 | 9.3 | 1.5 |
| | Pr>F | 0.0014 | <.0001 | 0.0105 | 0.0071 | 0.0002 | 0.527 |
| | lsd (0.05) | 0.17 | 1.7 | 0.15 | 3.1 | 442.9 | ns |

**Table 5.** The 2023 effect of increasing $P_2O_5$ rates on yield and quality averaged across nitrogen rates.

| P2O5 Rate (lbs per acre) | Sugar | Tons per Acre | Percent Extractable Sugar | Extractable Sugar per Ton (lbs.) | Extractable Sugar per Acre (lbs.) | Percent Purity |
|---|---|---|---|---|---|---|
| 0 | 17.0 | 24.8 c | 14.2 | 284.5 | 7070.8 c | 90.1 |
| 15 | 17.1 | 28.9 b | 14.3 | 286.2 | 8295.0 b | 89.8 |
| 30 | 17.1 | 32.6 a | 14.3 | 286.5 | 9344.0 a | 90.1 |
| 45 | 17.1 | 33.6 a | 14.3 | 286.8 | 9637.1 a | 90.1 |
| 60 | 17.3 | 33.1 a | 14.5 | 289.1 | 9567.1 a | 89.9 |
| Mean | 17.1 | 30.6 | 14.3 | 286.6 | 8782.8 | 90.0 |
| CV% | 1.7 | 10.6 | 1.7 | 1.7 | 11.0 | 0.4 |
| Pr>F | 0.1689 | <.0001 | 0.2578 | 0.2578 | <.0001 | 0.182 |
| lsd (0.05) | ns | 2.68 | ns | ns | 793.21 | ns |

**Table 6.** The 2024 effect of increasing $P_2O_5$ rates on yield and quality averaged across nitrogen rates.

| P2O5 Rate (lbs per acre) | Sugar | Tons per Acre | Percent Extractable Sugar | Extractable Sugar per Ton (lbs.) | Extractable Sugar per Acre (lbs.) | Percent Purity |
|---|---|---|---|---|---|---|
| 0 | 17.5 | 32.7 b | 14.8 | 296.7 | 9675.6 b | 90.6 |
| 15 | 17.6 | 35.3 a | 14.9 | 298.8 | 10543.2 a | 90.7 |
| 30 | 17.4 | 35.4 a | 14.8 | 295.1 | 10444.9 a | 90.7 |
| 45 | 17.4 | 35.1 a | 14.8 | 295.8 | 10375.2 a | 90.8 |
| 60 | 17.4 | 35.6 a | 14.8 | 295.7 | 10532.5 a | 90.9 |
| Mean | 17.5 | 34.8 | 14.8 | 296.4 | 10314.3 | 90.8 |
| CV% | 1.5 | 6.8 | 1.8 | 1.8 | 6.1 | 0.6 |
| Pr>F | 0.1945 | 0.0210 | 0.5976 | 0.4977 | 0.0081 | 0.4811 |
| lsd (0.05) | ns | 1.9 | ns | ns | 521.3 | ns |

**Table 7.** The 2025 effect of increasing $P_2O_5$ rates on yield and quality averaged across nitrogen rates.

| P2O5 Rate (lbs per acre) | Sugar | Tons per Acre | Percent Extractable Sugar | Extractable Sugar per Ton (lbs.) | Extractable Sugar per Acre (lbs.) | Percent Purity |
|---|---|---|---|---|---|---|
| 0 | 15.1 | 26.6 b | 12.9 | 258.4 | 6860.5 b | 92.0 |
| 15 | 15.1 | 28.6 ab | 12.9 | 257.1 | 7363.5 ab | 91.8 |
| 30 | 15.2 | 29.5 a | 12.8 | 256.0 | 7557.4 a | 91.1 |
| 45 | 15.0 | 29.7 a | 12.8 | 256.5 | 7617.2 a | 92.0 |
| 60 | 15.2 | 30.5 a | 13.0 | 259.2 | 7881.0 a | 92.0 |
| Mean | 15.1 | 29.0 | 12.9 | 257.4 | 7455.9 | 91.8 |
| CV% | 1.8 | 9.3 | 1.9 | 1.9 | 9.3 | 1.5 |
| Pr>F | 0.4866 | 0.0114 | 0.4414 | 0.4775 | 0.0128 | 0.4391 |
| lsd (0.05) | ns | 2.2 | ns | ns | 571.8 | ns |

**Table 8.** The effect of increasing rates of phosphorus and nitrogen analyzed as an RCBD with the addition of a starter fertilizer treatment of 3 gal 6-24-6 mixed with 3 gal of water/A in 2024.

| Entry | N Rate (lbs per acre) | P2O5 Rate (lbs per acre) | Sugar | Tons per Acre | Percent Extractable Sugar | Extractable Sugar per Ton (lbs.) | Extractable Sugar per Acre (lbs.) | Percent Purity |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 17.7 | 28.9 i | 15.0 | 299.3 | 8641.8 h | 90.7 |
| 2 | 0 | 15 | 17.7 | 33.0 efgh | 15.0 | 300.8 | 9930.0 efg | 90.8 |
| 3 | 0 | 30 | 17.5 | 32.7 fgh | 14.9 | 297.9 | 9729.9 fg | 91.0 |
| 4 | 0 | 45 | 17.5 | 30.8 hi | 14.9 | 298.6 | 9195.1 gh | 91.1 |
| 5 | 0 | 60 | 17.3 | 31.5 ghi | 14.7 | 293.3 | 9219.6 gh | 91.1 |
| 6 | 45 | 0 | 17.5 | 35.0 cdef | 14.8 | 295.4 | 10332.7 cdef | 90.7 |
| 7 | 45 | 15 | 17.6 | 34.1 defg | 15.0 | 299.5 | 10210.1 cdef | 90.9 |
| 8 | 45 | 30 | 17.4 | 35.7 bcdef | 14.8 | 295.0 | 10535.9 bcdef | 90.7 |
| 9 | 45 | 45 | 17.3 | 36.6 abcd | 14.6 | 292.6 | 10687.3 abcde | 90.7 |
| 10 | 45 | 60 | 17.6 | 36.2 abcde | 15.0 | 298.8 | 10824.6 abcd | 90.9 |
| 11 | 115 | 0 | 17.5 | 34.1 defgh | 14.8 | 295.3 | 10052.3 defg | 90.5 |
| 12 | 115 | 15 | 17.5 | 38.9 ab | 14.8 | 296.0 | 11489.5 a | 90.5 |
| 13 | 115 | 30 | 17.4 | 37.9 abc | 14.7 | 292.4 | 11069.0 abc | 90.4 |
| 14 | 115 | 45 | 17.5 | 38.0 abc | 14.8 | 296.3 | 11243.2 ab | 90.7 |
| 15 | 115 | 60 | 17.4 | 39.2 a | 14.8 | 294.9 | 11553.4 a | 90.9 |
| 16 | 45 | Starter | 17.8 | 35.7 bcdef | 15.1 | 301.9 | 10779.1 abcde | 90.7 |
| | | Mean | 17.5 | 34.9 | 14.8 | 296.8 | 10343.3 | 90.8 |
| | | CV% | 1.4 | 6.6 | 1.7 | 1.8 | 6.0 | 0.5 |
| | | Pr>F | 0.1581 | <.0001 | 0.2722 | 0.285 | <.0001 | 0.7932 |
| | | lsd (0.05) | ns | 3.3 | ns | ns | 883.6 | ns |

**Table 9.** The effect of increasing rates of phosphorus and nitrogen analyzed as an RCBD with the addition of a starter fertilizer treatment of 3 gal 6-24-6 mixed with 3 gal of water/A in 2025.

| Entry | N Rate (lbs per acre) | P2O5 Rate (lbs per acre) | Sugar | Tons per Acre | Percent Extractable Sugar | Extractable Sugar per Ton (lbs.) | Extractable Sugar per Acre (lbs.) | Percent Purity |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 15.2 | 25.5 f | 13.0 abcd | 259.1 abcde | 6609.7 f | 92.0 |
| 2 | 0 | 15 | 15.1 | 26.6 ef | 12.9 abcde | 257.5 abcdef | 6851.9 ef | 91.9 |
| 3 | 0 | 30 | 15.2 | 27.2 def | 12.9 abcde | 258.4 abcdef | 7024.0 def | 91.8 |
| 4 | 0 | 45 | 15.0 | 26.8 ef | 12.9 abcde | 257.0 bcdef | 6885.2 ef | 92.1 |
| 5 | 0 | 60 | 15.3 | 27.4 def | 13.1 ab | 261.1 abc | 7160.0 cdef | 92.1 |
| 6 | 45 | 0 | 15.3 | 26.4 ef | 13.1 a | 261.7 ab | 6896.6 ef | 92.0 |
| 7 | 45 | 15 | 15.2 | 29.6 bcde | 13.0 abc | 260.2 abcd | 7687.3 abcde | 92.0 |
| 8 | 45 | 30 | 15.4 | 29.7 bcde | 12.6 e | 251.4 f | 7467.7 bcdef | 89.5 |
| 9 | 45 | 45 | 15.2 | 30.9 abcd | 12.9 abcde | 258.5 abcdef | 8000.9 abc | 91.8 |
| 10 | 45 | 60 | 15.4 | 29.9 bcde | 13.2 a | 264.3 a | 7897.3 abcd | 92.2 |
| 11 | 115 | 0 | 14.9 | 27.8 cdef | 12.7 bcde | 254.3 cdef | 7075.3 cdef | 91.9 |
| 12 | 115 | 15 | 14.9 | 29.8 bcde | 12.7 dce | 253.6 def | 7551.2 bcdef | 91.4 |
| 13 | 115 | 30 | 15.1 | 31.7 ab | 12.9 abcd | 258.4 abcdef | 8180.6 ab | 91.9 |
| 14 | 115 | 45 | 14.9 | 31.4 abc | 12.7 bcde | 254.0 cdef | 7965.7 abcd | 92.0 |
| 15 | 115 | 60 | 14.8 | 34.1 a | 12.6 de | 252.2 ef | 8585.6 a | 91.7 |
| 16 | 45 | Starter | 15.2 | 28.3 bcdef | 13.1 ab | 260.7 abcd | 7369.9 bcdef | 92.2 |
| | | Mean | 15.1 | 28.9 | 12.9 | 257.6 | 7450.5 | 91.8 |
| | | CV% | 1.9 | 9.0 | 2.0 | 2.0 | 9.1 | 1.5 |
| | | Pr>F | 0.1901 | 0.0014 | 0.0298 | 0.0284 | 0.0043 | 0.5368 |
| | | lsd (0.05) | ns | 3.7 | 0.36 | 7.2 | 965.7 | ns |