Tomato Nitrogen Trial on Clay and Loam Soil Types during 2023, 2024 and 2025, Ridgetown Campus

Evaluation prepared for the Ontario Tomato Research Institute

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Introduction (and explanation of treatment differences):

An error was made the first year of this trial, as nitrogen rates were expressed in kg/acre when they should have been in lbs/acre. The technician at the time was not familiar with vegetable production and didn't question these rates, which were essentially 2.2 times greater than intended. This continued in 2024 when the technician used fertilizer weight calculations required per plot, which were made the previous year. The error was finally recognized in the spring of 2025 and rates were adjusted to match rates used in the previous 2 years. Therefore, nitrogen rates common across the 3 year trials were 0, 110, 220, and 330 lbs/acre. In 2025 only, the rates 165 and 275 lbs/acre were included as well. Nitrogen rates in the report tables remain as kg/ac; please refer to Table 1 below for the conversions.

Table 1. Common Treatments (2023, 2024 and 2025) vs. 2025 Treatments:

Treatment	2023 & 2024 (kg/ac)	2023 & 2024 (lbs/ac)	2025 (kg/ac)	2025 (lbs/ac)
1	**0 kg/ac**	0 lbs/ac	**0 kg/ac**	0 lbs/ac
2	**50 kg/ac**	110 lbs/ac	**50 kg/ac**	110 lbs/ac
3	**100 kg/ac**	220 lbs/ac	75 kg/ac	165 lbs/ac
4	**150 kg/ac**	330 lbs/ac	**100 kg/ac**	220 lbs/ac
5	**200 kg/ac**	440 lbs/ac	125 kg/ac	275 lbs/ac
6	**250 kg/ac**	550 lbs/ac	**150 kg/ac**	330 lbs/ac

Bold fonts indicate the common nitrogen treatments during 2023, 2024 and 2025

Experimental Design:

The tomato trial was set up with four replications in a strip block design. Three different tomato varieties (C337, H1014, and H3406) were tested. The two main factors being tested were:

1. Nitrogen fertilization rate
2. Environment (Year and Soil type)

The nitrogen fertilization treatments had 6 rates (see Table 1 above).

For environment there were 2 different sites, both on the Ridgetown Campus Research Farm included in the study over 3 years:

A) Clay soil type in 2023
B) Loam soil type in 2023
C) Clay soil type in 2024
D) Loam soil type in 2024
E) Clay soil type in 2025
F) Loam soil type in 2025

Different nitrogen rates were applied to the two soil types for each of the three tomato varieties. The plots were 8 meters long, with 45 cm spacing between rows and between plants, using a commercial twin row RJ transplanter. The plots were 1.5 meters wide. The data was analyzed using SAS software. To check the data's normality, the Shapiro-Wilk test was used, and residual plots were checked to confirm the variance assumptions. The Tukey HSD test was used to compare means, with a 95% confidence level ($\alpha=0.05$).

Data Collection:

- Plant Biomass (dry weight from 3 plants):
  - 2023: measured 8 weeks after planting
  - 2024: measured after harvest (due to plant loss in some plots)
  - 2025: measured 8 weeks after planting
- Plant Survival Count

Data collection at harvest Time:

- Yield (from 6 plants)
  - Red fruit
  - Green fruit
  - Breaker fruit
  - Rotten fruit

Field Management:

The fields were pre-treated with a burn-down herbicide before applying phosphorus and potassium fertilizers based on soil tests. Potash and 0-45-0 fertilizers were used to avoid interfering with nitrogen treatments. The cultivar C337 was used as a buffer row between areas treated with different nitrogen rates.

Each planting season received a PRE and POST herbicide program, as well as in the 2024 and 2025 (only in clay soil type) season the threshold of Colorado potato beetles was high and therefore the insecticide Admire and Pounce were administered. A fungicide program was implemented with a spray every 10-12 days, in 2024 and 2025 the fungicides (Bravo, Zampro and Quadris) were selected to focus on late blight that was a concern in the Chatham- Kent area.

Planting and Harvest Dates:

Table 2. Planting/Harvest dates and herbicide program for tomato trials over 3 years.

Year	Planting Date	Harvest Dates
2023	Loam: May 26, Clay: May 19	Loam: Sept 13–29, Clay: Sept 6–20
2024	Loam & Clay: May 23	Loam: Sept 4–11, Clay: Aug 27–Sept 3
2025	Loam & Clay: May 27	Loam: Aug 29, Sep 2 and October 3, Clay: Sept 29,30 and Oct 1

Plant survival was taken after planting. In 2024, plant biomass was collected at harvest due to high plant loss in some plots. Plants biomass measured 8 weeks after planting in 2023 and 2025. The plant biomass was dried down minus the plant fruit. Plots were harvested when 80% of the fruit across the varieties appeared red. At harvest, 6 plants per plot were picked, graded into red, green, breaker, and rotten fruits, and the yield was calculated in Kg then converted into Tonnes/Ha.

Results and Conclusions:

C337 (Table 3,3.1,3.2)

Plant Survival (%)

Plant survival ranged from 75.00–92.87%, with no significant differences among N rates, though a slight decline was noted at the highest N rate (150 kg/ac) in ENV A (Clay, 2023). Survival remained high (83–88%) across treatments in ENV B (Loam, 2023) with minimal nitrogen effect indicates stable establishment under loam soil conditions. Both clay and loam environments supported high plant survival (>80%), with little influence from nitrogen fertilization in 2023. Survival ranged from 86.55–98.10%, peaking at 50 kg N/ac under ENV C (Clay, 2024), indicates a slight positive response to moderate nitrogen levels. Very high survival (93–100%) across all treatments under ENV D (Loam, 2024), showing minimal nitrogen effect. Loam soil provided favorable conditions for uniform establishment in 2024. Excellent survival across environments, with nearly 100% survival achieved in loam soil (ENV D, 2024). Survival ranged from 82.70–89.55%, showing only minor variation among nitrogen rates under ENV E (Clay, 2025). It suggests good establishment regardless of N application. Survival remained consistently high (96–100%) in ENV F (Loam,2025), with several treatments achieving full plant survival (100%). Loam soil maintained near-perfect plant survival, while clay soils showed slightly lower but still strong survival levels in 2025 (Table 3.).

A significant treatment × environment interaction was observed for C337 plant survival, indicating that the effect of nitrogen varied slightly across soil types and years. However, plant survival remained consistently high across all treatments, typically exceeding 80%. Loam soils (ENVs B, D, and F) consistently recorded the highest plant survival (up to 100%), suggesting superior soil aeration and water balance that promote strong establishment. In contrast, clay soils (ENVs A, C, and E) exhibited slightly lower survival, particularly at the highest nitrogen rate (150 kg/ac), where mild reductions were observed. Moderate nitrogen levels (50–100 kg/ac) occasionally enhanced survival, particularly under clay conditions in 2024, but differences were generally not significant. Overall, these results indicate that C337 exhibits excellent establishment potential across environments, with nitrogen having minimal effect on plant survival (Table 3.).

Red Fruit Yield (Tonnes/Ha)

Under control (0 kg/acre), performance was generally low, ranging from 36.67 to 129.65 Tonnes/Ha across environments (Table 3.1). Loam soils, particularly ENV B and ENV D, exhibited higher values (up to 129.65 Tonnes/Ha) compared to clay soils (36.67–54.30), indicating better inherent fertility and nutrient availability in loam conditions. Increasing nitrogen to 50 kg/acre resulted in a noticeable improvement across all soils, with overall values ranging from 57.97 to 142.32. Loam soils continued to outperform clay soils, with

ENV B showing the highest response (142.32), while clay soils such as ENV E and ENV C displayed moderate increases.

Further enhancement was evident at 100 kg/acre, where the performance range widened substantially (51.00–163.55). This treatment produced the highest recorded values across all environments, particularly in ENV B (Loam) and ENV A (Clay), suggesting that 100 kg/acre represents an optimal nitrogen level for most soil types. However, beyond this level, responses tended to stabilize or decline slightly. At 150 kg/acre, the range was 64.72–130.97 Tonnes/Ha, with clay soils such as ENV A and ENV C benefiting the most, while loam soils like ENV B and ENV F showed reduced gains compared to the 100 kg/acre treatment. This indicates that excessive nitrogen application in loam soils may lead to nutrient saturation or leaching, reducing efficiency.

Table 3.1 presents the interaction between nitrogen treatment levels and soil types (clay and loam) over the years 2023, 2024, and 2025). Loam soils consistently exhibited higher performance than clay soils across all nitrogen levels, reflecting their superior structure and nutrient dynamics. The 100 kg/acre nitrogen treatment produced the broadest and most favorable response range, suggesting it is the most effective rate under both soil types. However, for clay soils, increasing the nitrogen rate up to 150 kg/acre may still provide additional benefits, while loam soils achieve optimal performance at 100 kg/acre. These results highlight the importance of adjusting nitrogen application based on soil type to maximize efficiency and yield potential.

Total Yield (Tonnes/Ha)

Yields ranged from 99.15–114.63 t/ha under ENV D (Loam, 2023), with only small differences among treatments. Nitrogen fertilization substantially improved yield in clay soil of 2024 trial but had minimal effect in loam. Table 3.2 showing that yield increased steadily from 52.12 t/ha (0 kg/ac) to 101.35 t/ha (100 kg/ac), before dropping slightly at 150 kg/ac (82.87 t/ha) in ENV E (Clay, 2025). It observed that moderate nitrogen rates (100 kg/ac) optimized yield on clay soil. Yield increased from 121.57 t/ha (0 kg/ac) to 157.60 t/ha (150 kg/ac) under ENV F (Loam, 2025), suggesting a consistent positive response to nitrogen under loam conditions. Loam soils again outperformed clay soils, with optimal yields achieved at 100–150 kg N/ac in year 2025.

A significant treatment × environment interaction was observed for C337 total fruit yield, indicating that nitrogen effects varied depending on soil type and year. In general, loam soils (ENVs B, D, and F) produced higher total yields than clay soils (ENVs A, C, and E) across all nitrogen levels. The yield response to nitrogen was strongest in clay environments, where yields increased substantially with higher nitrogen rates, while in loam soils, the response was smaller, but yields were consistently high (Table 3.2). The optimal nitrogen rate ranged between 100–150 kg/ac, beyond which yields tended to stabilization or slightly decline. The year 2023 showed the highest yield potential overall, suggesting favorable growing conditions. These results are demonstrated in table 3.2 that

C337 benefits from moderate to high nitrogen application, particularly in clay soils where nitrogen availability is often more limited, whereas loam soils maintain high productivity even at lower nitrogen levels.

H1014 (Table 4,4.1,4.2)

Plant Survival (%)

Table 4. showing under ENV A (Clay, 2023), the plant survival ranged from 80.35–92.87% across treatments, showing no significant difference among nitrogen levels. It recorded that nitrogen had minimal influence on plant survival in clay soil for 2023. Survival was high (≈88–94%), with all treatments statistically similar under ENV B (Loam). Both clay and loam soils in year 2023 supported high plant survival, with no clear response to nitrogen rate. Survival ranged between 90–94%, peaking at 100 kg N/ac (94.25%) under ENV C (Clay, 2024). Slight increase in survival with moderate nitrogen rates. Very high survival (90–96%) across treatments under ENV D (Loam, 2024), with a small peak at 100 kg N/ac (96.20%). Loam soil consistently produced excellent survival with limited nitrogen effect. Plant survival remained uniformly high (>90%) across environments in year 2024, with only minor variation due to nitrogen (Table 4.). Survival varied more widely (74.05–90.40%) under ENV E (Clay, 2025), with the lowest survival at 100 kg N/ac (74.05%). It showed that possible negative impact of higher nitrogen on plant survival under clay conditions in 2025. Survival remained consistently high (95–100%) under ENV F (Loam, 2025), with 100% survival achieved at both 0 and 50 kg N/ac. Loam soil provided ideal conditions for plant establishment and persistence. Loam soil maintained near-perfect survival in 2025, while clay soil showed greater variability and sensitivity to high nitrogen.

A significant treatment × environment interaction was observed for H1014 plant survival, indicating that nitrogen effects varied slightly across soil types and years. In general, plant survival was high (>85%) across all environments, with loam soils (ENVs B, D, and F) consistently showing the highest survival rates. Nitrogen treatment had minimal impact on survival, though slight improvements were observed at moderate rates (50–100 kg N/ac) in some environments. In 2025, a minor reduction in survival was noted at higher nitrogen levels (100 kg N/ac) on clay soils, possibly due to stress related to soil compaction or excess nutrient concentration. Across all years, loam soils demonstrated superior plant establishment and uniform stand persistence, likely due to better soil aeration and drainage. These results suggest that H1014 exhibits strong survival capacity across environments, and nitrogen fertilization does not substantially affect survival except under extreme soil or climatic conditions (Table 4.).

Red Fruit Yield (Tonnes/Ha)

Table 4.1 showing nitrogen treatments across different environments and soil types from 2023 to 2025 revealed distinct responses depending on both nitrogen level and soil texture. Under control (0 kg/acre), the recorded values ranged from 35.45 to 140.57, indicating the natural variation in productivity among environments. The lowest value was observed in ENV C (Clay) (35.45), while the highest occurred in ENV B (Loam) (140.57). Overall, loam soils (ENV B, D, F) exhibited higher baseline performance compared to clay soils (ENV A, C, E), suggesting greater inherent fertility and better nutrient availability in loam environments even without nitrogen input.

When nitrogen was increased to 50 kg/acre, the performance range expanded to 45.82–182.77, showing an evident positive response to nitrogen fertilization. All environments demonstrated improvement over the control treatment, with ENV B (Loam) recording the maximum value of 182.77, while ENV E (Clay) remained the lowest at 45.82. This indicates that loam soils respond more efficiently to lower nitrogen levels due to improved nutrient mobility and uptake. Clay soils, on the other hand, exhibited moderate gains, likely due to slower nitrogen mineralization and retention dynamics.

Further increase to 100 kg/acre resulted in a performance range of 75.37–159.58, showing consistent enhancement in most environments, particularly in ENV A (Clay) (151.00) and ENV B (Loam) (159.58). The overall improvement in this range indicates that nitrogen availability was near optimal, supporting stronger growth and productivity. Interestingly, both clay and loam soil exhibited favorable responses at this level, suggesting that 100 kg/acre provides sufficient nitrogen for most soil types without causing inefficiency or nutrient loss.

At the highest level of 150 kg/acre, the observed range narrowed slightly to 74.90–143.67. While productivity remained high in some environments particularly ENV A (Clay) (133.22) and ENV B (Loam) (143.67) the increase was less pronounced compared to the 100 kg/acre treatment.

The data illustrates the interaction between nitrogen treatments (0, 50, 100, and 150 kg/acre) and soil types (clay and loam) over the years 2023-2025 (Table4.1). At the lowest nitrogen level (0 kg/acre), loam soils (ENV B, D, F) generally showed higher values than clay soils (ENV A, C, E), with ENV B (loam) performing the best. As nitrogen levels increased to 50 kg/acre, a noticeable improvement occurred across all environments, particularly in loam soils, with ENV B achieving the highest response. At 100 kg/acre, performance remained relatively high for loam soils, while clay soils, especially ENV E, showed substantial gains. By the highest nitrogen treatment (150 kg/acre), the results varied more, with clay soils (ENV A, C, E) showing notable improvements, while loam soils like ENV B and D saw a slight decline compared to the 50 kg/acre treatment.

Total Yield (Tonnes/Ha)

Yield increased from 80.42 t/ha (0 kg N/ac) to 167.22 t/ha (100 kg N/ac) under ENV A (Clay, 2023) but slightly declined at 150 kg N/ac (137.67 t/ha). Table 4.2 indicates that yield peaked at 100 kg N/ac under clay conditions. Yield appeared sharply from 146.78 t/ha at 0 kg N/ac to 194.23 t/ha at 50 kg N/ac under ENV B (Loam, 2023) and (~187 t/ha at 100 kg N/ac). Loam soils produced higher yields than clay soils at all nitrogen rates in 2023.: Yields were generally lower under ENV C (Clay, 2024), ranging 40.17–118.80 t/ha. Maximum yield occurred at 150 kg N/ac. It observed that strong N response under clay, possibly due to N limitation. Yields were relatively consistent (≈108–114 t/ha) across treatments under ENV D (Loam, 2024), showing little response to nitrogen. Clay soil responded positively to higher N in year 2024, while loam soil reached a yield stabilization early. Yields were low across treatments (≈46–102 t/ha) under ENV E (Clay, 2025), with the highest yield at 100 kg N/ac (101.70 t/ha). Yields were much higher, increasing from 114.15 t/ha (0 kg N/ac) to 159.45 t/ha (100 kg N/ac), with a slight decrease at 150 kg N/ac (153.58 t/ha) under ENV F (Loam, 2025). Optimal yield observed at 100 kg N/ac. Again, loam soils outperformed clay soils. The best yields were obtained with 100 kg N/ac in 2025 (Table 4.2).

A significant treatment × environment interaction was observed for H1014 total yield, indicating that nitrogen response varied by soil type and year. Generally, loam environments produce higher yields than clay environments across all nitrogen levels. The response to nitrogen was strongest at moderate rates (50–100 kg N/ac), beyond which yields either stabilized or declined. Table 4.2 shows, higher nitrogen rates (100–150 kg N/ac) were often required to reach maximum yields in clay soils, suggesting lower nitrogen use efficiency compared with loam soils. These results highlight the importance of site-specific nitrogen management for optimizing yield potential of H1014 across different soil environments.

H3406 (Table 5, 5.1, 5.2)

Plant Survival (%)

Plant survival remained constant at 88.40% for all N rates (0–100 kg/ac) under ENV A (Clay, 2023) but dropped slightly to 75.85% at 150 kg/ac (Table 5). It shows that excessive nitrogen (150 kg/ac) may have slightly reduced plant survival on clay soil. Survival was generally high (≈84–95%), with the highest survival at 50 kg/ac (94.67%) ENV B (Loam, 2023). Results show that moderate nitrogen improved survival slightly compared to the control. Loam soils showed slightly higher plant survival than clay soils in 2023, and 50 kg/ac appeared optimal. Survival was high across treatments (≈88–95%) under ENV C (Clay, 2024), with the highest survival (95.22%) at 50 kg/ac. Nitrogen had a mild positive effect on plant survival. Very high survival (≈96–97%) across all treatments, showing little to no difference among nitrogen rates in ENV D (Loam, 2024). As per output, loam soil provided favorable conditions regardless of nitrogen level. Excellent plant survival (>95%) on loam, stable survival on clay. Minimal influence of nitrogen treatment in 2024 (Table 5.). Survival decreased to 75–83%, with the highest at 50 kg/ac (82.70%) under ENV E (Clay, 2025). Very high survival (90–99%) across all N rates under ENV F (Loam, 2025), with a slight peak at 150 kg/ac (99.05%). Loam soil maintained strong resilience under all nitrogen levels. Plant survival was again higher on loam soils in 2025, showing consistent robustness and tolerance to N rate variation.

A significant treatment × environment interaction was observed for H3406 plant survival, indicating that nitrogen effects differed between soil types and years. Overall, plant survival was consistently higher in loam environments (ENVs B, D, and F) than in clay environments. In most cases, moderate nitrogen levels (50 kg/ac) resulted in slightly higher survival compared to no nitrogen, while very high rates (150 kg/ac) occasionally reduced survival, particularly in clay soils. Across all years, loam soils supported stable survival rates above 90%, suggesting better aeration, drainage, and nutrient balance. In contrast, clay environments exhibited more variability, likely due to poorer soil structure and moisture stress. These findings indicate that H3406 performs more reliably under loam conditions and that moderate nitrogen applications can optimize plant establishment and persistence without compromising stand survival (Table 5).

Red Fruit Yield (Tonnes/Ha)
The data show in table 5.1 that nitrogen application had a significant impact on performance across different soil types and environments. Under control (0 kg/acre), values ranged from 42.30 to 128.13, indicating the natural fertility differences among environments. Loam soils (particularly ENV B and ENV F) performed better than clay soils, reflecting their higher nutrient availability and better soil structure. Increasing the nitrogen rate to 50 kg/acre improved performance in all environments, with values ranging from 62.22 to 141.78. The highest response was observed in ENV B (Loam) (141.78), while clay soils such as ENV C and ENV E showed moderate increases.

A further rise to 100 kg/acre resulted in a wider and higher range (63.15 to 181.65), with maximum performance in ENV B (Loam) (181.65) and ENV F (Loam) (178.90), indicating that this level provided optimal nitrogen availability for most soils. Clay soils also showed improvement, though the response was less pronounced compared to loam soils. At the highest rate, 150 kg/acre, the range narrowed slightly to 87.60–168.45, suggesting that further nitrogen addition produced diminishing returns, particularly in loam environments. However, clay soils like ENV C (101.50) continued to respond positively, showing that heavier soils may benefit from slightly higher nitrogen levels.

Nitrogen treatments (0, 50, 100, and 150 kg/acre) interact with different soil types (clay and loam) over the years 2023-2025. At the lowest nitrogen level (0 kg/acre), loam soils (ENV B, D, F) generally showed higher values than clay soils (ENV A, C, E), with ENV F (loam) performing the best. Increasing the nitrogen level to 50 kg/acre resulted in noticeable improvements across all environments, particularly in loam soils, where ENV F and ENV B showed strong responses. At 100 kg/acre, loam soils (ENV B and F) continued to show high performance, while clay soils showed more varied responses, with ENV E showing significant gains. The highest nitrogen treatment (150 kg/acre) led to moderate improvements in clay soils (ENV A, C, E) but slightly decreased values in loam soils (ENV B, D, F) compared to the 100 kg/acre treatment. (Table 5.1).

Total Yield (Tonnes/Ha)

Yields increased from 65.10 t/ha (0 kg N/ac) to a peak of 152.10 t/ha (100 kg N/ac) under ENV A (Clay, 2023), before declining slightly at 150 kg N/ac (129.32 t/ha). Table 5.2 showing that 100 kg N/ac was optimal for clay soil in 2023 (Table 5.2.). Yields increased sharply with nitrogen, from 151.23 t/ha (0 kg N/ac) to 228.33 t/ha (100 kg N/ac), the highest recorded across all environments under ENV B (Loam, 2023). It demonstrates strong positive response to N on loam soil. Loam soil produced much higher yields than clay soils, with optimum response at 100 kg N/ac in 2023. Yield increased steadily with nitrogen under ENV C (Clay, 2024, from 50.00 to 111.05 t/ha, showing a strong positive response. Yields remained relatively stable (≈91–117 t/ha) across treatments in ENV D (Loam, 2024), indicating minimal nitrogen effect in this loam environment. Table 5.2 showing nitrogen significantly boosted yield in clay soil but had limited effect in loam, suggesting environmental or seasonal variation affected N response in 2024. Yield increased from 62.10 to 129.05 t/ha, showing a strong positive response to nitrogen, especially up to 100 kg N/ac under ENV E (Clay, 2025). Yields ranged from 133.87 to 196.82 t/ha under ENV F (Loam, 2025), with the highest yield at 100 kg N/ac, followed by a decline at 150 kg N/ac. Loam soil again outperformed clay soil, but both showed optimal total fruit yield around 100 kg N/ac in 2025 (Table 5.2)

A significant treatment × environment interaction was observed for H3406 total fruit yield, indicating that nitrogen response varied across soil types and years. In general, loam soils (ENVs B, D, and F) produced substantially higher total yields than clay soils (ENVs A, C, and E). Over all years, total fruit yield increased with nitrogen rate up to approximately 100 kg N/ac, beyond which yields tended to stabilize or decline slightly. The strongest nitrogen responses were observed in 2023 (both soils) and in 2024-2025 under clay conditions, suggesting that nitrogen availability was more limiting in those environments. Conversely, loam soil often reached maximum yields at moderate nitrogen levels, reflecting higher nutrient use efficiency. These results are emphasized in table 5.2. that optimal total fruit yield in H3406 is achieved at moderate nitrogen rates (around 100 kg N/ac), particularly under loam conditions, while excessive nitrogen does not further enhance productivity and may reduce efficiency in clay environments.

C337, H1014 and H3406 during 2025 (Table 6,7,8)

Plant Survival (%)

Different nitrogen treatments (ranging from 0 to 250 kg /acre) affected plant survival for three different plant varieties (C337, H1014, H3406) in two different environmental conditions (Table 6) clay soil (ENV E) and loam soil (ENV F). Treatment by Environment Interaction in Table 6 highlights that the effect of nitrogen treatment on plant survival is influenced by both the amount of nitrogen and the type of soil (clay vs. loam). For example, the same nitrogen treatment could result in different survival rates depending on whether the plant is grown in clay or loam soil.

In general, survival rates in loam soil tend to be higher than in clay soil, especially at higher nitrogen levels. However, the differences are not always large. Generally, survival rates are similar across nitrogen treatments in C 337, with a slight decrease in survival as the nitrogen amount increases, especially in clay soil. H1014 variety shows a trend of high survival rates across all treatments, with little difference between clay and loam soil. H3406 has more variability in survival rates, with the lowest survival observed at the highest nitrogen treatment (250 kg/ac) in both soil types, especially in clay soil.

Nitrogen treatments had a varied impact on plant survival depending on variety and soil type. Generally, higher nitrogen levels did not always improve survival, with some varieties showing a decline in survival at higher nitrogen doses, particularly in clay soil. The survival rates tended to be better in loam soil compared to clay soil for most varieties and treatments. This information can help determine the optimal nitrogen treatment for each plant varieties depending on soil type to maximize survival rates (table 6).

Red Fruit Yield (Tonnes/Ha)

The table 7. shows different nitrogen treatments (ranging from 0 to 250 kg per acre) affected red fruit yield (tonnes/ha) for three plant varieties (C337, H1014, H3406) in two different soil types: clay soil (ENV E) and loam soil (ENV F). Variety C337 shows a strong positive response to nitrogen, especially in clay soil (ENV E), where yields start at 36.67 tonnes/ha with no nitrogen and increase steadily to 88.90 tonnes/ha at 250 kg/acre, the highest for this variety. In loam soil (ENV F), yields were generally lower, peaking at 69.82 tonnes/ha at 200 kg/acre. Overall, C337 performs best with high nitrogen in clay soil, but loam soil doesn’t support it as strongly.

Variety H1014 has a more mixed response to nitrogen. In clay soil (ENV E), its yield increases from 38.50 tonnes/ha (no nitrogen) to 93.05 tonnes/ha at 250 kg/acre, though the increase isn’t as consistent. In loam soil (ENV F), it starts at 84.17 tonnes/ha and peaks at 103.25 tonnes/ha at 100 kg/acre, but beyond that, the yield slightly decreases with more nitrogen. H1014 does well in both soils, but excessive nitrogen in loam soil seems to reduce its yield slightly, with the best performance around 100–150 kg/acre.

Variety H3406 shows the most consistent and highest response to nitrogen, especially at higher levels. In clay soil (ENV E), yields rise from 45.20 tonnes/ha (0 kg/ac) to 98.80 tonnes/ha at 250 kg/acre. In loam soil (ENV F), its yield jumps dramatically from 106.40 tonnes/ha (0 kg/ac) to an impressive 178.90 tonnes/ha at 250 kg/acre, the highest overall yield in the table. H3406 thrives with high nitrogen, particularly in loam soil, where 250 kg/acre produces the best yield (Table 7.).

Total Fruit Yield (Tonnes/Ha)

Different nitrogen fertilizer levels (0–250 kg/ac) affected total fruit yield for three plant varieties (C337, H1014, and H3406) grown in two environments presented in table 8: clay soil (ENV E) and loam soil (ENV F). A significant treatment by environment interaction means that nitrogen influences yield differently depending on the soil type. For all three varieties, total fruit yield generally increased with higher nitrogen application, especially in loam soil (ENV F). In clay soil (ENV E), yield increased with nitrogen up to moderate levels, but the improvement was less pronounced compared to loam. Loam soil (ENV F) consistently produced higher total yields than clay soil (ENV E) for all varieties and nitrogen rates. The highest yields were recorded in loam soil at higher nitrogen levels (200–250 kg/ac). Yield increased steadily with nitrogen, reaching its peak in loam soil at 200 kg/ac (157.77 T/Ha) in C337. H1014: Yield increased sharply with nitrogen, peaking at 250 kg/ac in loam soil (159.45 T/Ha). H3406: This variety responded most strongly to nitrogen, achieving the highest overall yield (196.83 T/Ha) at 250 kg/ac in loam soil. Nitrogen fertilization had a strong positive impact on total fruit yield, particularly in loam soil. Among the three varieties, H3406 achieved the highest yield under high nitrogen levels, followed by H1014 and C337. These results are suggested in table 8. that applying nitrogen up to 200–250 kg/ac in loam soils can maximize fruit yield potential, whereas in clay soils, yield gains are smaller at higher nitrogen rates.

Conclusion:

Across all varieties (C337, H1014, and H3406), plant survival remained high (>80%) across environments, with loam soils consistently supporting better establishment than clay soils. Nitrogen had minimal effect on survival, though moderate rates (50–100 kg N/ac) slightly improved it, while excessive nitrogen occasionally reduced survival in clay conditions. Note that the highest rates of nitrogen in the first 2 years (2023 and 2024) were made in error and were excessive.

Red fruit and total yields increased with nitrogen application up to 100–150 kg N/ac, particularly in loam soils. Loam soil consistently outperformed clay soils due to better structure and nutrient efficiency. Among varieties, H3406 showed the strongest response to higher nitrogen rates, achieving the highest yields overall, followed by H1014 and C337.

In 2025, the highest total yields occurred under loam conditions at 200–250 kg N/ac, while clay soils showed smaller gains beyond moderate nitrogen levels. Overall, moderate nitrogen rates (100–150 kg N/ac) optimized yield and survival in clay soils, whereas higher rates benefited loam soils. These findings emphasize the need for soil-specific nitrogen management to maximize productivity and efficiency.

Table 3. Effects of nitrogen (N) fertilizer treatments on plant survival (%) of C337 across six environments (A–F) over three growing seasons (2023–2025).

	2023		2024		2025	
Nitrogen Treatment	ENV A (Clay)	ENV B (Loam)	ENV C (Clay)	ENV D (Loam)	ENV E (Clay)	ENV F (Loam)
1 (0 kg/ac)	90.20a-g	87.50a-g	97.12 ab	100.00 a	83.67a-g	100.00 a
2 (50 kg/ac)	92.87a-g	84.82a-g	98.10 ab	99.05 ab	89.55a-g	99.10 ab
3 (100 kg/ac)	81.25a-g	83.02a-g	86.55a-g	93.27a-g	84.62a-g	96.17abc
4 (150 kg/ac)	75.00efg	86.82a-g	89.42a-g	95.20 abcd	82.70a-g	100.00 a

$^{a\text{-}g}$ Means within column followed by the same letter are not different according to Tukey's HSD at α=0.05.
Means with no shared letters differ significantly ($p < 0.05$).

ENV: Environment

Table 3.1. Effect of nitrogen (N) fertilizer treatments on red fruit yield (Tonnes/Ha) of C337 across six environments (A–F) over three growing seasons (2023–2025).

Nitrogen Treatment	2023		2024		2025	
	ENV A (Clay)	ENV B (Loam)	ENV C (Clay)	ENV D (Loam)	ENV E (Clay)	ENV F (Loam)
1 (0 kg/ac)	54.30o-t	129.65a-j	38.80st	92.97e-t	36.67st	69.10l-t
2 (50 kg/ac)	86.45f-t	142.32a-g	59.65n-t	100.30e-r	57.97n-t	67.60l-t
3 (100 kg/ac)	115.45b-n	163.55abc	60.27m-t	93.70e-t	88.90f-t	51.00p-t
4 (150 kg/ac)	130.97a-j	128.87a-j	103.12d-q	101.95d	75.65j-t	64.72l-t

$^{a\text{–}j}$ Means within column followed by the same letter are not different according to Tukey's HSD at α=0.05.
Means with no shared letters differ significantly ($p < 0.05$). **ENV:** Environment

Table 3.2. Effects of nitrogen (N) fertilizer treatments on total fruit yield (Tonnes/Ha) of C337 across six environments (A–F) and three years (2023–2025).

	2023		2024		2025	
Nitrogen Treatment	ENV A (Clay)	ENV B (Loam)	ENV C (Clay)	ENV D (Loam)	ENV E (Clay)	ENV F (Loam)
1 (0 kg/ac)	64.47s-x	139.12c-p	45.17wx	99.15i-x	52.12u-x	121.57f-t
2 (50 kg/ac)	94.55j-x	162.35a-i	71.65q-x	114.63h-v	64.37s-x	151.27b-m
3 (100 kg/ac)	141.33c-o	189.55a-e	88.52m-x	105.90h-x	101.35h-x	123.33
4 (150 kg/ac)	150.80b-m	146.77b-n	123.87e-t	114.42h-v	82.87n-x	157.60b-l

[a–x] Means within column followed by the same letter are not different according to Tukey's HSD at α=0.05.
Means with no shared letters differ significantly ($p < 0.05$).

ENV: Environment

Table 4. Effect of nitrogen (N) treatments on plant survival (%) of H1014 across six environments (A–F) and three years (2023–2025).

	2023		2024		2025	
Nitrogen Treatment	ENV A (Clay)	ENV B (Loam)	ENV C (Clay)	ENV D (Loam)	ENV E (Clay)	ENV F (Loam)
1 (0 kg/ac)	90.20a-g	93.77a-g	90.40a-g	94.25a-f	88.47a-g	100.00a
2 (50 kg/ac)	92.87a-g	88.40a-g	92.32a-g	95.20abcd	87.50a-g	100.00a
3 (100 kg/ac)	87.50a-g	88.40a-g	94.25a-f	96.20abc	74.05g	95.20abcd
4 (150 kg/ac)	80.35a-g	89.30a-g	91.35a-g	90.37a-g	90.40a-g	98.10ab

[a-g] Means within column followed by the same letter are not different according to Tukey's HSD at α=0.05.
Means with no shared letters differ significantly ($p < 0.05$).

ENV: Environment

Table 4.1. Effects of nitrogen (N) fertilizer treatments on red fruit yield (Tonnes/Ha) of H1014 across six environments (A–F) over three growing seasons (2023–2025).

Nitrogen Treatment	2023		2024		2025	
	ENV A (Clay)	ENV B (Loam)	ENV C (Clay)	ENV D (Loam)	ENV E (Clay)	ENV F (Loam)
1 (0 kg/ac)	67.32l-t	140.57a-h	35.45t	103.88d-q	38.50st	84.17g-t
2 (50 kg/ac)	112.35b-o	182.77a	69.90k-t	102.33d-q	45.82qrst	93.17e-t
3 (100 kg/ac)	151.00a-e	159.58abcd	75.37j-t	95.25e-s	93.05e-t	92.67e-t
4 (150 kg/ac)	133.22a-j	143.67a-f	113.07b-o	108.42c-p	74.90j-t	98.70e-r

[a-j] Means within column followed by the same letter are not different according to Tukey's HSD at α=0.05.
Means with no shared letters differ significantly ($p < 0.05$).

ENV: Environment

Table 4.2. Effect of nitrogen (N) treatments on total yield (Tonnes/Ha) of H1014 across six environments (A–F) and three years (2023–2025).

	2023		2024		2025	
Nitrogen Treatment	ENV A (Clay)	ENV B (Loam)	ENV C (Clay)	ENV D (Loam)	ENV E (Clay)	ENV F (Loam)
1 (0 kg/ac)	80.42o-x	146.78b-n	40.17x	107.60h-w	45.75wx	114.15h-v
2 (50 kg/ac)	122.67h-t	194.23abcd	77.67o-x	107.95h-w	51.47uvwx	130.83c-r
3 (100 kg/ac)	167.22a-h	187.03a-f	93.05k-x	100.85i-x	101.70h-x	159.45b-k
4 (150 kg/ac)	137.67c-q	164.35a-i	118.80h-t	114.25h-v	82.10n-x	153.58b-m

[a-x] Means within column followed by the same letter are not different according to Tukey's HSD at α=0.05.
Means with no shared letters differ significantly ($p < 0.05$).

ENV: Environment

Table 5. Effect of nitrogen (N) treatments on plant survival (%) of H3406 across six environments (A–F) and three years (2023–2025).

	2023		2024		2025	
Nitrogen Treatment	ENV A (Clay)	ENV B (Loam)	ENV C (Clay)	ENV D (Loam)	ENV E (Clay)	ENV F (Loam)
1 (0 kg/ac)	88.40a-g	93.77a-g	89.42a-g	97.12ab	79.82b-g	98.15ab
2 (50 kg/ac)	88.40a-g	94.67abcde	95.22abcd	96.17abc	82.70a-g	98.10ab
3 (100 kg/ac)	88.40a-g	83.95a-g	88.47a-g	97.12ab	75.00c-g	90.42a-g
4 (150 kg/ac)	75.85defg	85.72a-g	89.45	97.15ab	76.92c-g	99.05ab

[a-g] Means within column followed by the same letter are not different according to Tukey's HSD at α=0.05.
Means with no shared letters differ significantly ($p < 0.05$).

ENV: Environment

Table 5.1. Effect of nitrogen (N) treatments on red fruit yield (Tonnes/Ha) of H3406 across six environments (A–F) and three years (2023–2025).

Nitrogen Treatment	2023		2024		2025	
	ENV A (Clay)	ENV B (Loam)	ENV C (Clay)	ENV D (Loam)	ENV E (Clay)	ENV F (Loam)
1 (0 kg/ac)	53.42p-t	128.13a-k	42.30rst	83.80g-t	45.20qrst	106.40c-p
2 (50 kg/ac)	77.02i-t	141.78a-g	62.22m-t	108.42c-p	81.75h-t	118.73b-m
3 (100 kg/ac)	119.33b-k	181.65a	63.15m-t	85.20f-t	98.80e-r	178.90a
4 (150 kg/ac)	109.00c-p	168.45ab	101.50d-q	87.60f-t	90.37f-t	135.10a-i

[a-h] Means within column followed by the same letter are not different according to Tukey's HSD at α=0.05.
Means with no shared letters differ significantly ($p < 0.05$).

ENV: Environment

Table 5.2. Effects of nitrogen (N) treatments on the total fruit yield (Tonnes/Ha) of H3406 across six environments (A–F) and three growing seasons (2023–2025).

Nitrogen Treatment	2023		2024		2025	
	ENV A (Clay)	ENV B (Loam)	ENV C (Clay)	ENV D (Loam)	ENV E (Clay)	ENV F (Loam)
1 (0 kg/ac)	65.10r-x	151.23b-m	50.00vwx	91.40l-x	62.10t-x	133.87c-q
2 (50 kg/ac)	92.00k-x	184.78a-g	74.82n-x	116.70h-u	98.97i-x	138.80c-p
3 (100 kg/ac)	152.10b-m	228.33a	82.12	93.60j-x	129.05d-s	196.82abc
4 (150 kg/ac)	129.32d-s	211.00ab	111.05h-v	94.07j-x	122.20f-t	157.72b-k

[a-x] Means within column followed by the same letter are not different according to Tukey's HSD at α=0.05.
Means with no shared letters differ significantly ($p < 0.05$).

ENV: Environment

Table 6. Effect of nitrogen (N) treatments on plant survival (%) of C337, H1014, H3406 across two environments (E and F, 2025).

Nitrogen Treatment	C337		H1014		H3406	
	ENV E (Clay)	ENV F (Loam)	ENV E (Clay)	ENV F (Loam)	ENV E (Clay)	ENV F (Loam)
1 (0 kg/ac)	90.32ab	100.01a	88.47ab	100.00a	79.82ab	98.15ab
2 (50 kg/ac)	89.12ab	100.04a	87.50ab	100.00a	82.70ab	98.10ab
3 (100 kg/ac)	87.89ab	98.17ab	83.65ab	98.10ab	84.62ab	96.17ab
4 (150 kg/ac)	80.67ab	100.04a	90.40ab	98.10ab	76.92b	99.05a
5 (200 kg/ac)	85.35ab	98.77a	82.70ab	100.00a	76.92ab	94.25ab
6 (250 kg/ac)	87.75ab	98.17ab	74.05b	95.20ab	75.00b	90.42ab

Tukey's HSD test (α = 0.05), means followed by the same letters (e.g., *a, b, ab*) within each column are **not significantly different**. For instance, nitrogen treatments showing the same letter grouping (such as *a* or *ab*) for a given genotype and environment indicate **no significant difference** in plant survival percentage.
ENV: Environment

Table 7. Effect of nitrogen (N) treatments on red fruit yield (Tonnes/Ha) of C337, H1014, H3406 across two environments (E and F, 2025).

Nitrogen Treatment	C337		H1014		H3406	
	ENV E (Clay)	ENV F (Loam)	ENV E (Clay)	ENV F (Loam)	ENV E (Clay)	ENV F (Loam)
1 (0 kg/ac)	36.67j	69.10e-j	38.50ij	84.17c-j	45.20hij	106.40cdef
2 (50 kg/ac)	57.97f-j	67.60e-j	45.82ghij	93.17c-h	81.75e-j	118.73bcd
3 (100 kg/ac)	76.55e-j	63.07f-j	68.77e-j	103.25cdefg	91.95c-h	138.05abc
4 (150 kg/ac)	75.65e-j	64.72f-j	74.90e-j	98.70cdefg	90.37c-h	135.10abcd
5 (200 kg/ac)	75.12e-j	69.82e-j	53.80ghij	86.12c-j	87.22c-j	162.32ab
6 (250 kg/ac)	88.90c-j	51.00ghij	93.05c-h	92.67c-h	98.80cdefg	178.90a

Tukey's HSD test (α = 0.05), treatments sharing the same letters (e.g., *a–d*) are **not significantly different** in red fruit yield within each variety and environment. This means that nitrogen treatments with common letter groupings (e.g., *abc* or *abcd*) exhibit statistically similar red fruit yields.
ENV: Environment

Table 8. Effect of nitrogen (N) treatments on total fruit yield (Tonnes/Ha) of C337, H1014, H3406 across two environments (E and F, 2025).

	C337		H1014		H3406	
Nitrogen Treatment	ENV E (Clay)	ENV F (Loam)	ENV E (Clay)	ENV F (Loam)	ENV E (Clay)	ENV F (Loam)
1 (0 kg/ac)	57.15f	121.87 b-f	45.75f	114.15b-f	62.10ef	133.88abcd
2 (50 kg/ac)	73.54def	132.12abcd	51.47f	130.82abcd	98.97cdef	138.80abcd
3 (100 kg/ac)	88.61cdef	124.47a-f	73.75def	142.42abcd	109.25cdef	159.43abc
4 (150 kg/ac)	90.38cdef	122.87b-f	82.10def	153.57abc	122.20b-f	157.73abc
5 (200 kg/ac)	89.97cdef	157.77abc	61.00ef	150.75abc	106.43cdef	181.95ab
6 (250 kg/ac)	97.62cdef	74.05def	101.70cdef	159.45abc	129.05a-e	196.83a

Tukey's HSD test (α = 0.05), means followed by identical letters (e.g., *a–f*) within a column are **not significantly different**. Thus, nitrogen treatments with overlapping letter groups (for example, *abc* or *cdef*) show **no statistically significant difference** in total fruit yield among genotypes across environments.
ENV: Environment