

**Final Report for**  
**Project 11620 (Task/Deliverable #5)**

**Protecting Water Quality Through the Use of Effective Water and Nutrient  
Management Practices for Strawberry Production**

**Submitted to**  
**Florida Department of Agriculture and Consumer Services**  
**June 18, 2007**

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5339 SR 579  
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**Cooperator:** Alicia Whidden, Multi-county extension agent  
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**Project Duration:** 3 years

**Requested Annual Funding Level:** \$70,000/year

**Introduction and Justification:**

Florida's growers produce the majority of the nation's winter crop fresh strawberries. With over 7000 acres dedicated to strawberries, the Hillsborough County's Plant City-Dover area has long been known as the "Winter Strawberry Capitol of the World". The farm value from strawberries was \$140 million in 2002-03, up from \$38 million twenty years ago. During that time, strawberry acreage has increased 40 percent, up from 5000 acres.

Strawberry producers are among the most unique agricultural producers in the state and most aggressive in adopting technological improvements.

They were one of first commodities to utilize plastic-mulched raised-bed culture in the 1960's. This allowed for soil sterilization, eliminating weeds, nematodes, soil borne insects and disease. The black plastic raised soil temperature for winter production and inhibited future weed germination. It also kept the berries out of the sand and reduced evaporative moisture loss.

Unfortunately, the plastic mulch also eliminated the possibility of augmenting fertility during the production cycle. Since Florida's strawberry production is during the winter, growers needed to freeze protect on occasion with overhead irrigation. By its very nature, this procedure wet the beds and leached nutrients from the beds during freeze protection. Since there was no way to determine before hand the number of freezes to come during a berry deal, growers would tend to fertilize on the high side, so there would be adequate fertility for the berry crop during the entire season.

The advent of microirrigation (drip) allowed growers to place a measured amount of water and fertility at the root zone to mirror the plants needs without over-fertilizing or moisture loss through evaporation. Drip irrigation has reduced the amount of water needed to produce a crop of strawberries by about half and has reduced the industry's rate of fertility by a third. Over 95 percent of the strawberry industry has embraced this technology.

However, because strawberries arrive as bare root transplants the plants must be established by overhead irrigation. Additionally, the growers still must utilize overhead irrigation for freeze protection as needed. This requires the growers to have both overhead and drip irrigation systems. To reduce groundwater pumped from the aquifer, over 45 percent of the state's acreage collects surface tailwater from the fields and reuses it.

The water conserved through these practices is well documented. As an industry, strawberries are using less water than they did twenty years ago, with forty percent more acreage. However, there is little information on the quality of the water in groundwater, in tailwater, or in surface water discharged from the farm during a storm event.

### **Project Objectives:**

The use of best management practices (BMP) for production of horticultural crops in Florida are being identified for producers to use to meet total maximum daily loadings (TMDL) regulations to minimize nutrient loading quantities in groundwater and surface water bodies. In some cases, producers adhering to approved BMP's may have "implied compliance" and considered exempt from liability if TMDL limits are exceeded.

The overall objective of this project is to evaluate the effectiveness of water and nutrient management practices for strawberry production

(concentrating on those contained in the Vegetable and Agronomic Crop BMPs manual) under a range of soil type and individual grower management levels. The ultimate goal of the project is assess the level of BMP use, demonstrate effectiveness, and encourage grower adoption of water and nutrient management practices that will reduce the potential for contamination to shallow groundwater, surface runoff and surface water bodies.

Achievement of this objective includes efforts to:

A) Develop and conduct a survey of strawberry growers to ascertain an industry-wide estimation of base-level fertilization and irrigation practices to gauge Best Management Practice adoption and to survey producers following Project completion to establish the degree of adoption and success BMP's designed to reduce groundwater contamination risks

B) Assess actual commercial crop production scenarios (including differences in soil type, management level, fertilization and irrigation practices) for nutrient load potential of nitrogen from subsurface leaching and surface runoff. This information would be valuable to ascertain the state of the industry with respect to management practices which are used to minimize potential for off-site movement of applied nutrients.

C) Use educational programs with results of field data, to assist growers in adopting water and fertilizer management technologies that will reduce the amount of N leaching each year from typical crop production systems.

Sample management practices in use for this portion of the project include conversion to drip irrigation, optimum fertilization rates including pre-plant and fertigation systems, improvement of plant establishment and freeze protection irrigation efficiency through re-design of in-place irrigation systems, use of tissue testing to better track actual crop-nutrient contents and thereby avoid over fertilization, etc.

## **Methodology**

- A) This objective will seek to assess on an industry-scale and within the grower-cooperator group participating the project, the pre- and post-study status of water and nutrient management practices. In addition, an effort to determine the economic impact of implementing BMP changes will be accomplished as part of the education process.
- B) Through extension and industry personnel, grower-cooperators will enlisted to allow surface and subsurface water sampling on a regular

basis (weekly) to ascertain the impact of present water and nutrient management practices on water quality. All grower-cooperator irrigation and fertilizer application information will be available in the process of evaluation. Groundwater sampling would involve the use of multi-level water samplers (allowing simultaneous sampling at multiple depths) to determine the amounts of soluble inorganic N in the shallow groundwater beneath grower/cooperator production fields and surface runoff sampling and for the same nutrient analyses to assess off-site discharge during rainfall and overhead irrigation events at each location. Surface water sampling will be accomplished using automated event sampling equipment and/or regularly scheduled surface samples of static water bodies. Analyses will be accomplished using a rapid flow analyzer (RFA) which employs a spectrophotometric method for determination of nitrate-N in water samples.

- C) This objective will be accomplished through ongoing education programs (newsletter articles, EDIS publications, educational workshops) making growers aware of information which will encourage the use of BMP's that reduce potential of movement of applied nutrients off-site.

#### **Anticipated Benefits:**

The most effective way to achieve adoption of BMP's is for growers to see them successfully in use by fellow growers. The benefits that would result from this study would be identification of effective BMP's that minimize any detrimental impact of applied nutrients on surface water and groundwater resources resulting from strawberry production. The industry survey conducted at the beginning and end of this project would provide evidence of those core practices which should be included in a BMP manual which is responsible for addressing strawberry production. The overall benefit to the public would be water quality protection of this natural resource.

## 2004-2005 Progress Report

The first year of this study was initiated in August 2004, by identifying grower/cooperators who:

- 1) had production fields containing specific soil types
- 2) were willing to share specific cultural management information
- 3) would allow water quality samples to be collected from production fields on a weekly basis.

Twenty sampling sites (shown in Figures 1-11) were identified and cooperative agreements were arranged with grower/cooperators and monitoring equipment was installed. A weekly water sampling scheme for strawberry production was implemented in November 2004 and continued through March 2005. Once strawberry production ceased, sampling continued at those locations where a double crop (i.e. melons, peppers, etc) was planted to follow the strawberries. This sampling scheme continued into mid June.

During the production season a survey (Table 1.) was developed to ascertain the production inputs and management practices of the grower cooperators. The results of the survey showed some variability in management practices, but nothing extremely divergent among sites. Generally, for a projected 120-day strawberry crop, producers were applying 0 to 30 lbs N as dry pre-plant fertilizer and 0.75-1.5 lbs N applied as liquid fertilizer per day. Irrigation applications ranged from 45 min/day to 3 hr/day depending on emitter flow rate and grower preference. However the majority of producers were applying irrigation water at 60 min/day. Fertilizer was injected at mid- to late-irrigation cycle with enough time left to flush the system before the irrigation cycle concluded. Specifically, the following general conclusions resulted from the responses to the survey:

- 1) growers use drip irrigation with overhead sprinklers for transplant establishment and cold protection
- 2) crops are planted mid to late October
- 3) growers use at least five different microirrigation tube types amongst the responses
- 4) growers use drip tube with 0.24 to 0.50 gpm/100 ft application rates
- 5) growers apply irrigation rates from 0.12 to 0.26 inches/A/day
- 6) ~ 50% of growers apply no dry pre-plant fertilizer
- 7) growers that do apply dry pre-plant fertilizer apply ~ 20 to 40 lb N per acre
- 8) growers apply ~ 1 lb N per acre per day liquid fertilizer
- 9) growers use experience to decide when and how much to irrigate (with a limited number using soil moisture measurements)
- 10) growers fertigate at the end of the cycle with ~15 to 30 flush time.

Soil types of the sites identified included Immokalee, Pomello, St. Johns, Seffner, Zolfo, Kesson, Ona, Taveres, Malabar, Lake, Gainesville, Candler, Fort Meade, and Myakka. All sites had dry season water table levels below 2 m, so a sampling modification of using a "wick"-type leachate collector (Figure 12) was implemented. This collector allowed for collection of water and nutrients leaching below the crop rooting zone and allowed an estimated of mass balance losses of N and water from the fields. An analysis of the results from the water quality sampling showed that most growers leached < 1lb NO<sub>3</sub>-N for the season but losses of >20 lb NO<sub>3</sub>-N for the season were measured (Figures 13-24). A comparison of NO<sub>3</sub>-N losses to soil type showed no significant relationship reinforcing the probability that NO<sub>3</sub>-N losses that do occur are more likely due management intensity.

Overall, based on these first year results, the strawberry grower/cooperators participating in this study seem to be doing an exceptional job of minimizing water and nutrient losses during the production season. Information from this first year of data collection will be presented at the Florida Strawberry Growers Association Agritech 2005 meeting this August.

**Table 1.                    Grower/Co-operator Cultural Information Sheet**

Site #: \_\_\_\_\_ Cultivar: \_\_\_\_\_

Planting Date(s): \_\_\_\_\_

Irrigation System(s): \_\_\_\_\_

Drip Tube Type: \_\_\_\_\_

Emitter Spacing: \_\_\_\_\_ Emitter Flow Rate: \_\_\_\_\_

Daily Runtimes (minutes):

Nov. \_\_\_\_\_ Dec. \_\_\_\_\_

Jan. \_\_\_\_\_ Feb. \_\_\_\_\_

Mar. \_\_\_\_\_ Apr. \_\_\_\_\_

Dry Fertilizer Analysis: \_\_\_\_\_

Dry Fertilizer Application Rate: \_\_\_\_\_

Liquid Fertilizer Analysis: \_\_\_\_\_

Liquid Fertilizer Application Rate:

Nov. \_\_\_\_\_ Feb. \_\_\_\_\_

Dec. \_\_\_\_\_ Mar. \_\_\_\_\_

Jan. \_\_\_\_\_ Apr. \_\_\_\_\_

How do you determine irrigation runtime?

At what point in an irrigation cycle do you inject fertilizer?

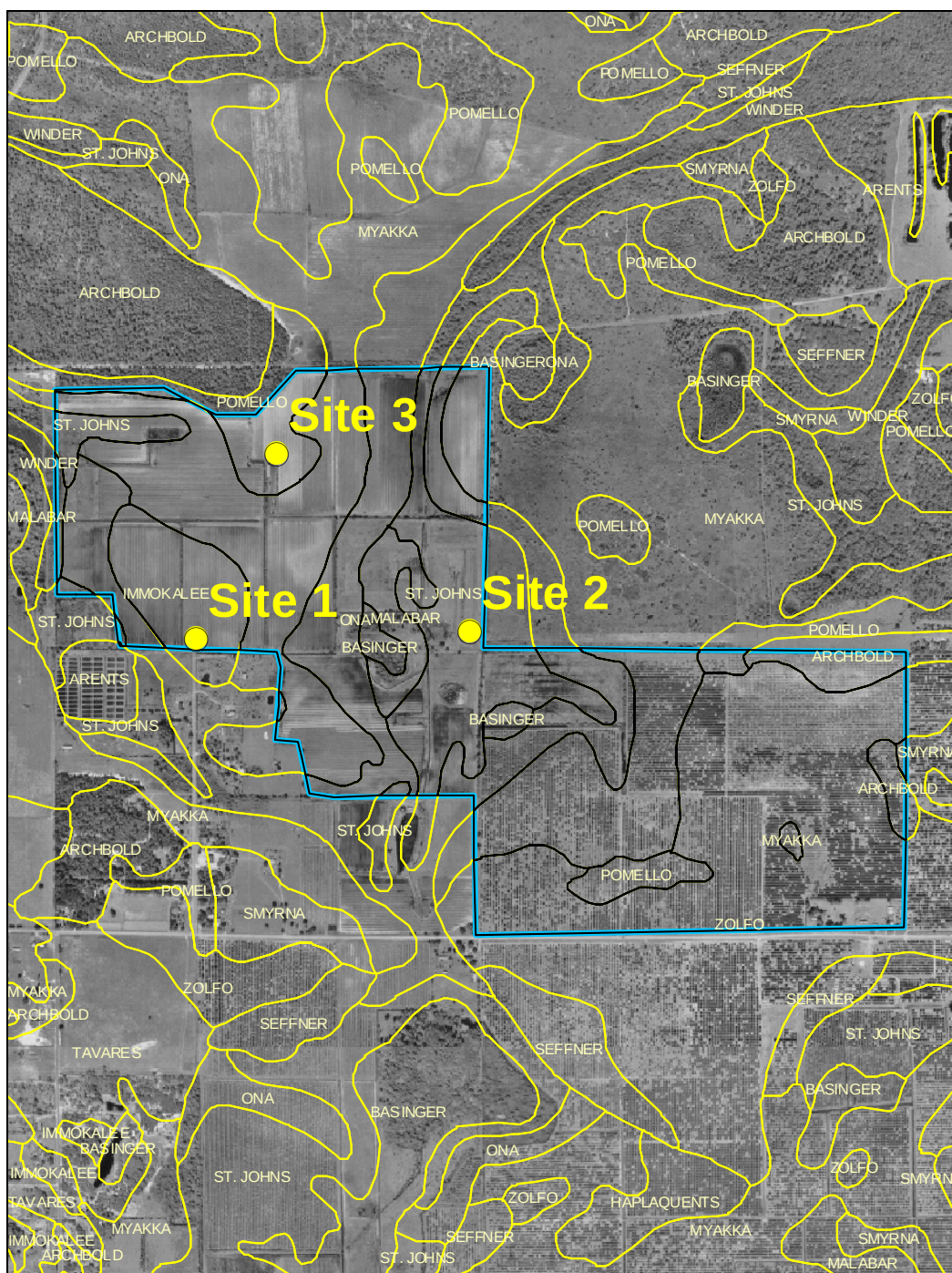


Figure 1



Figure 2



Figure 3



Figure 4



Figure 5

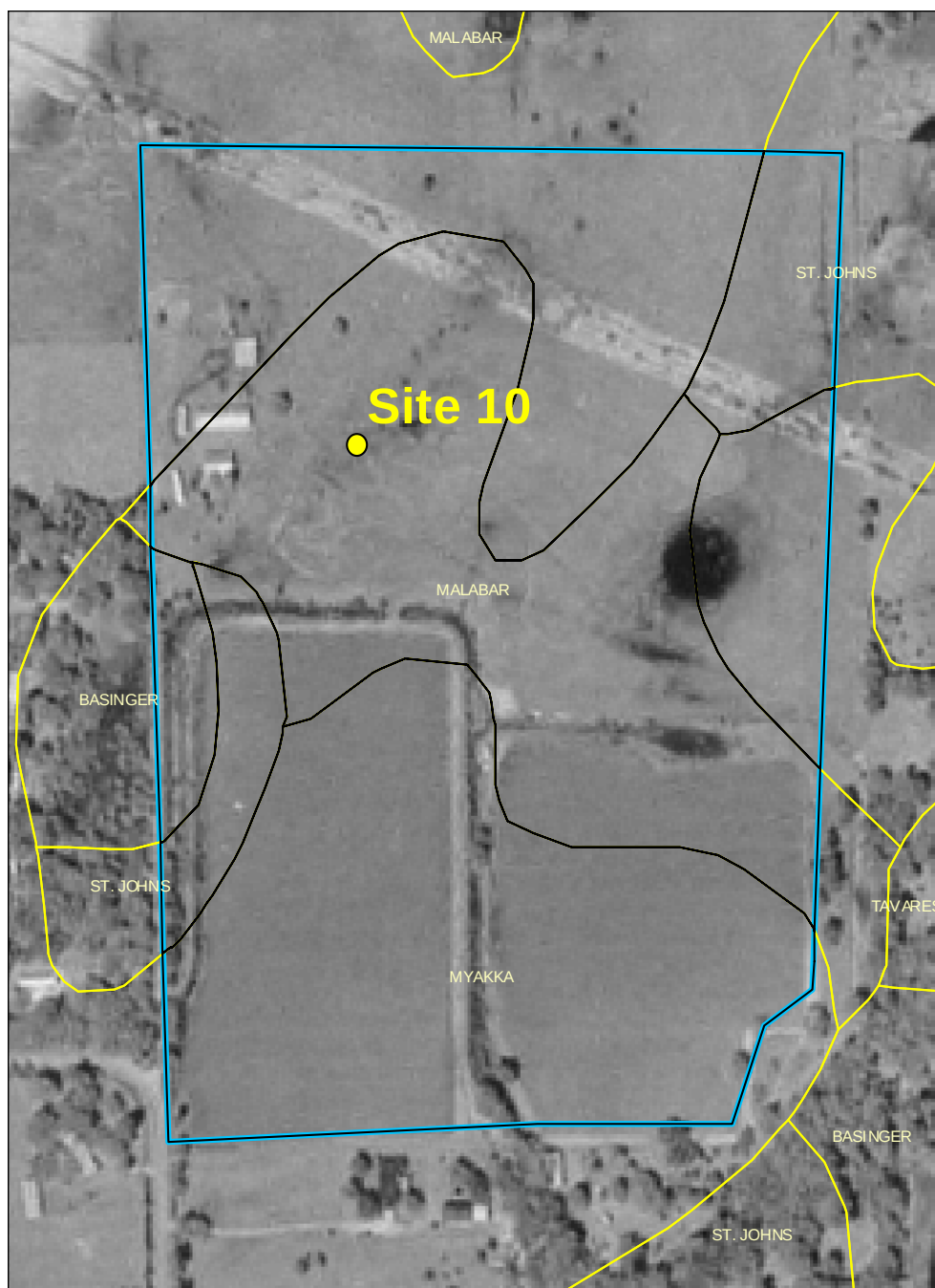


Figure 6



Figure 7

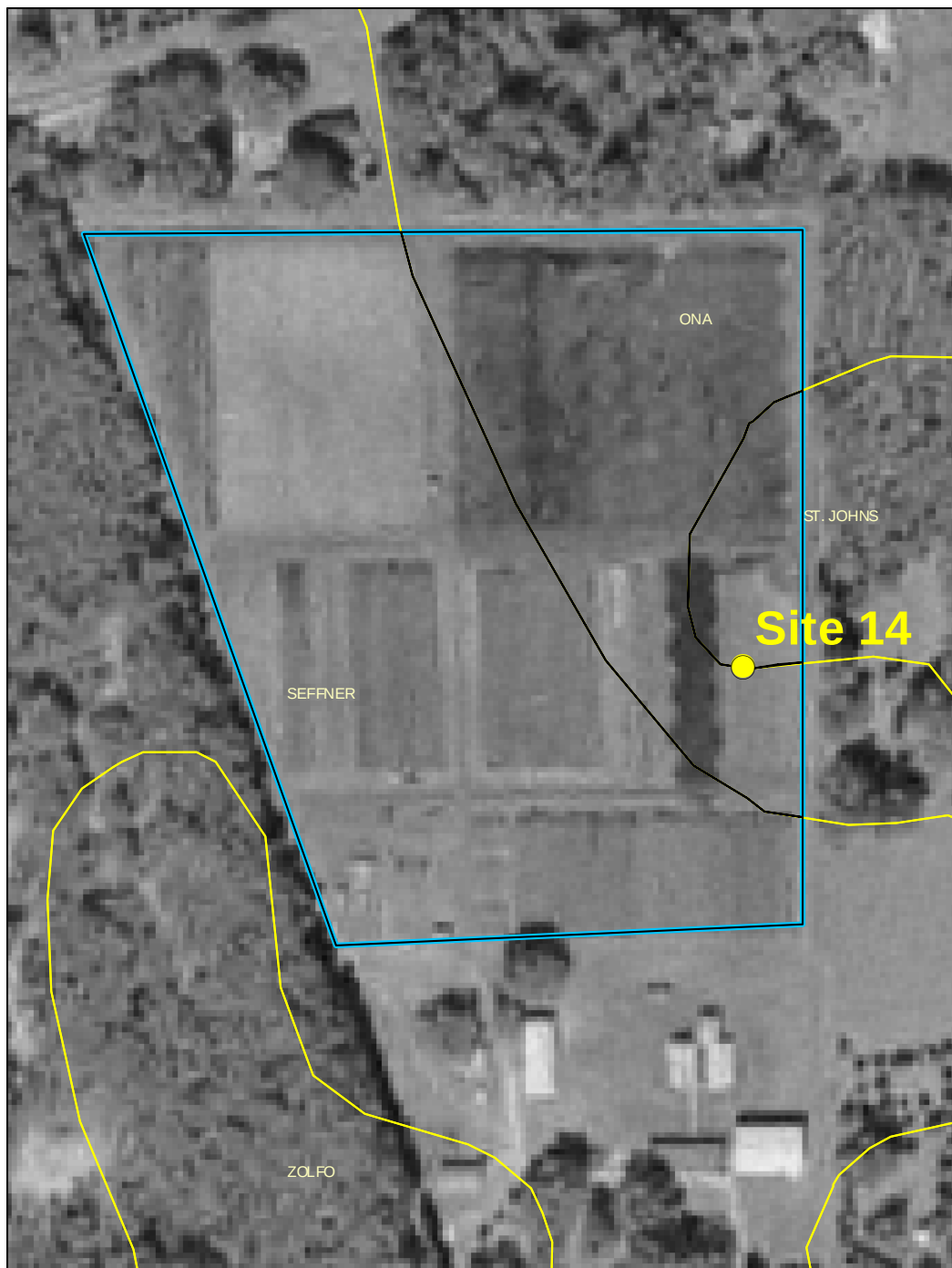


Figure 8

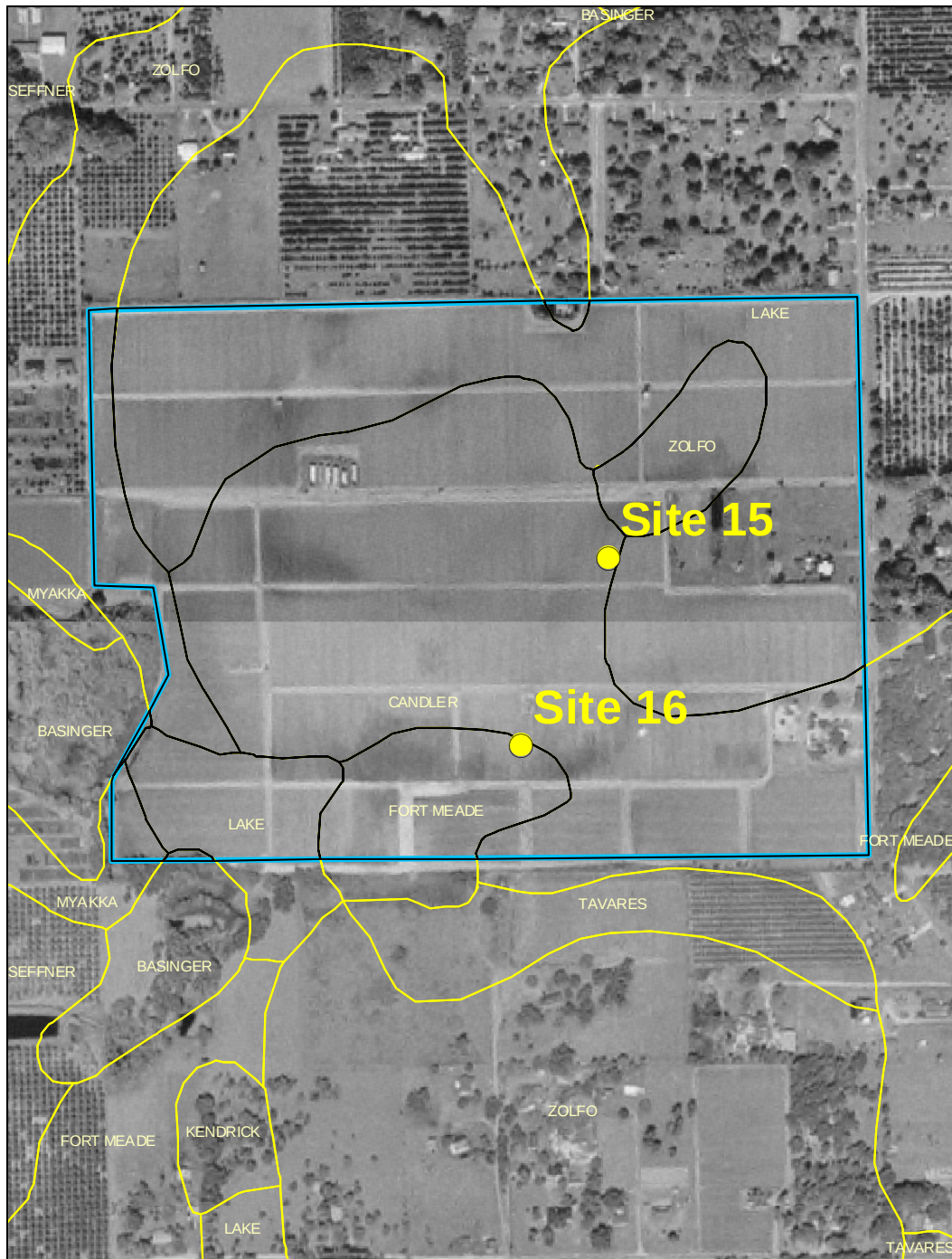


Figure 9

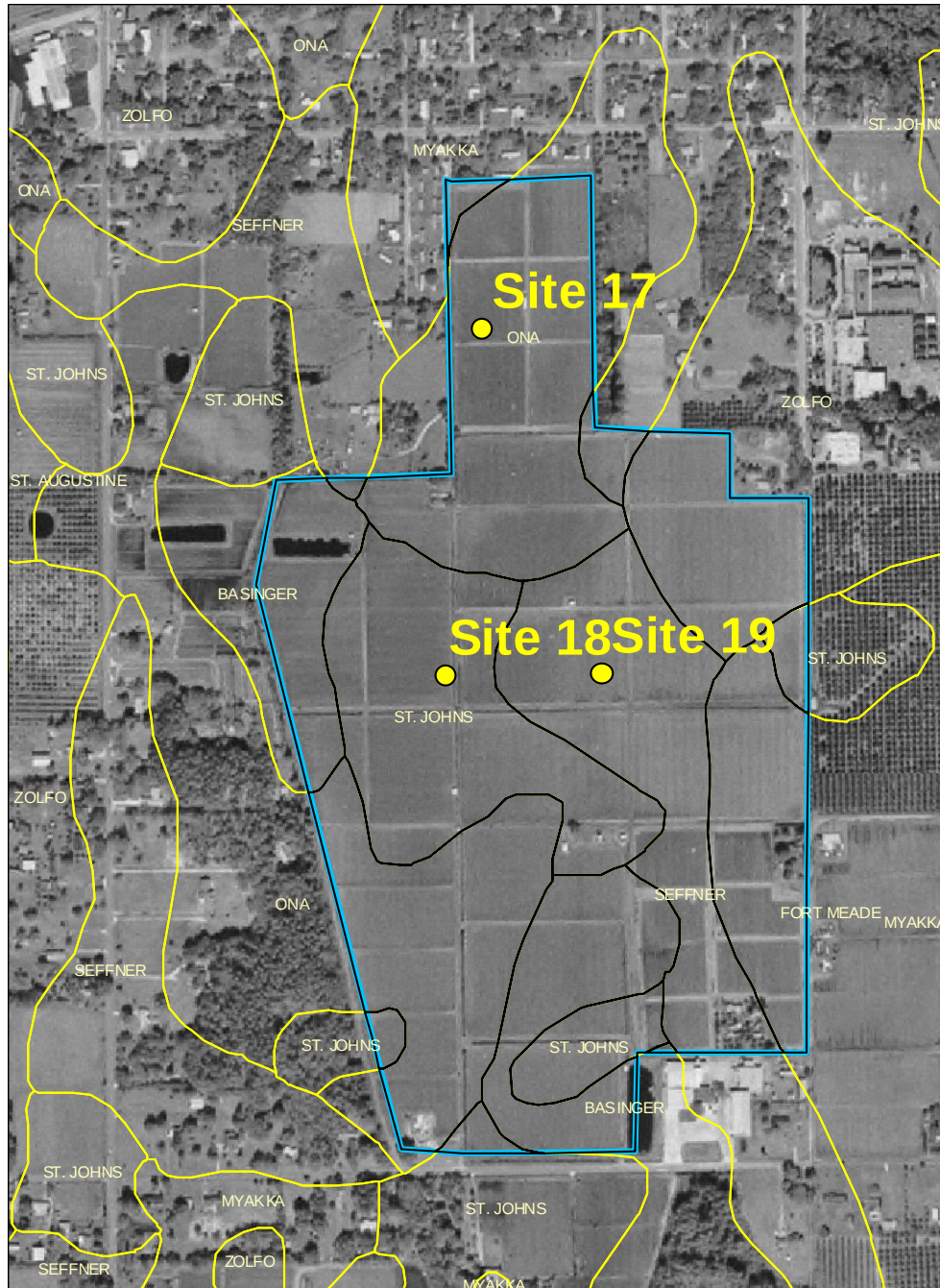


Figure 10



Figure 11

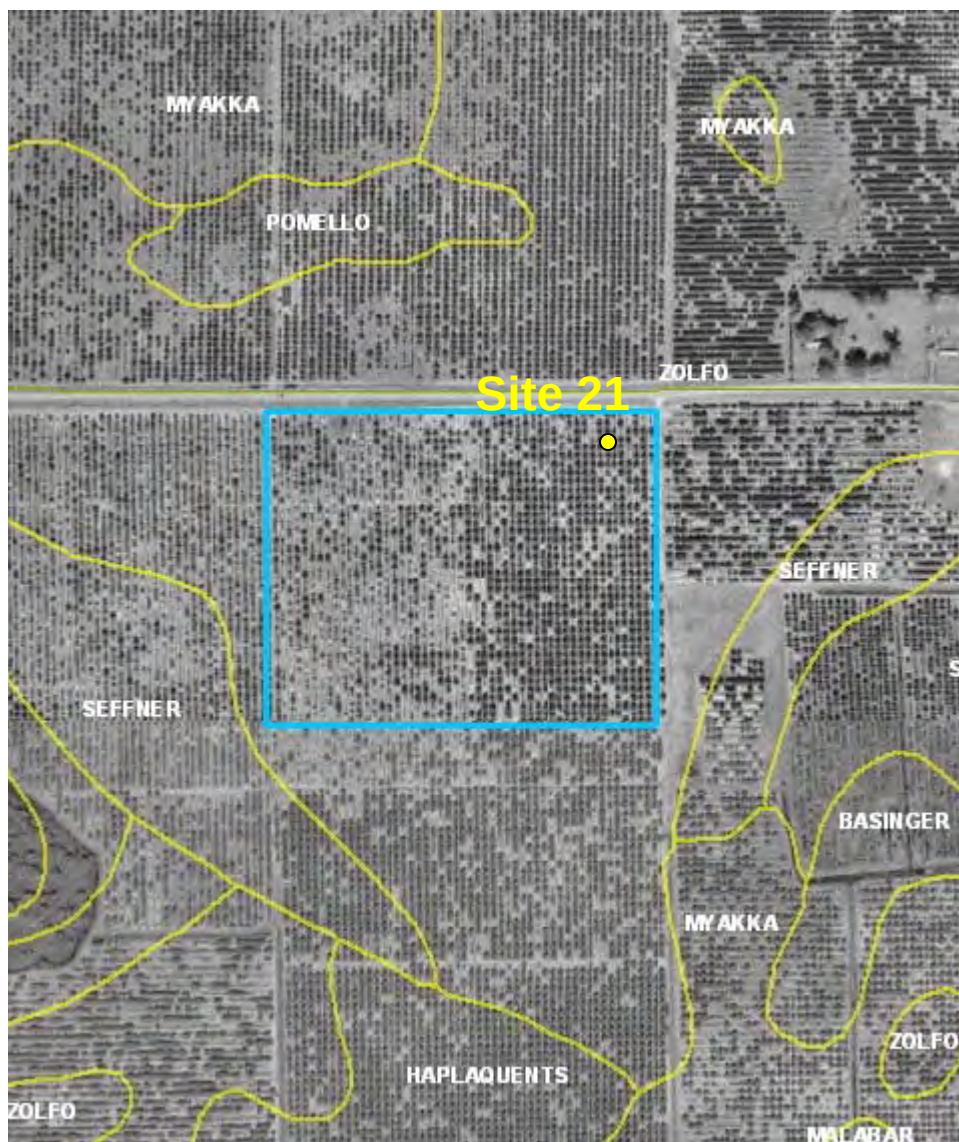


Figure 12

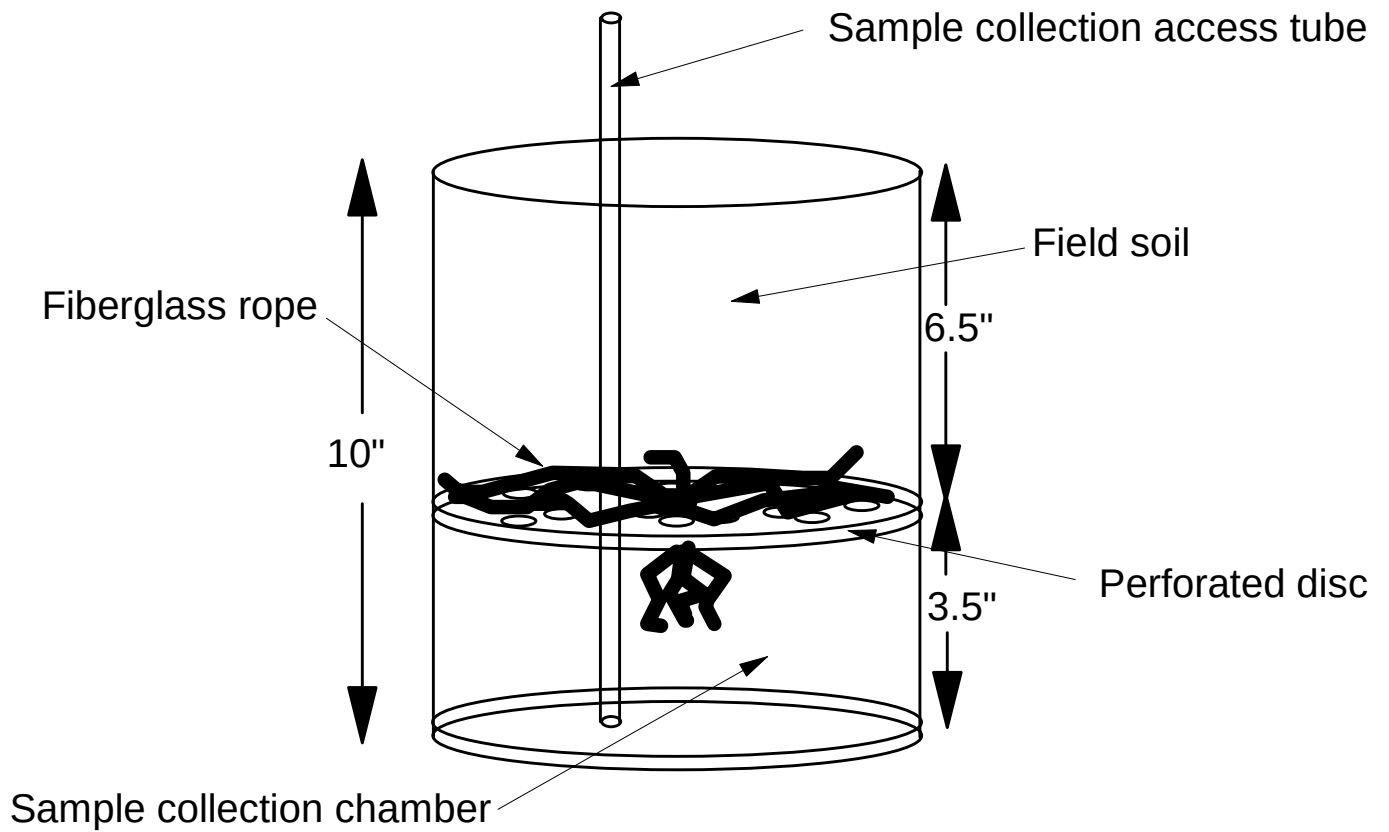


**Figure 13**

# Farm 1

## Sites 1, 2, and 3

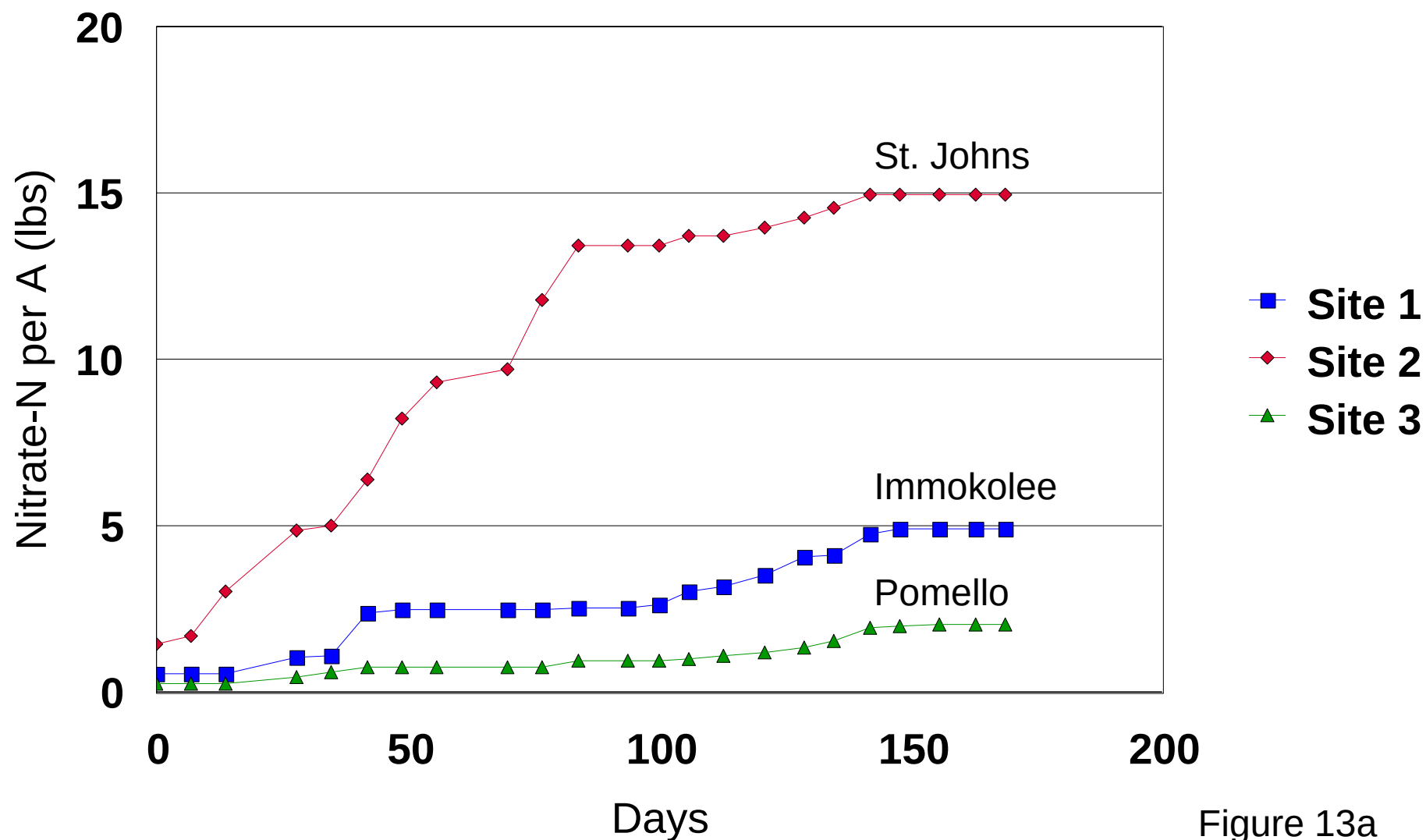


Figure 13a

## Farm 2

### Sites 4, 5, and 6

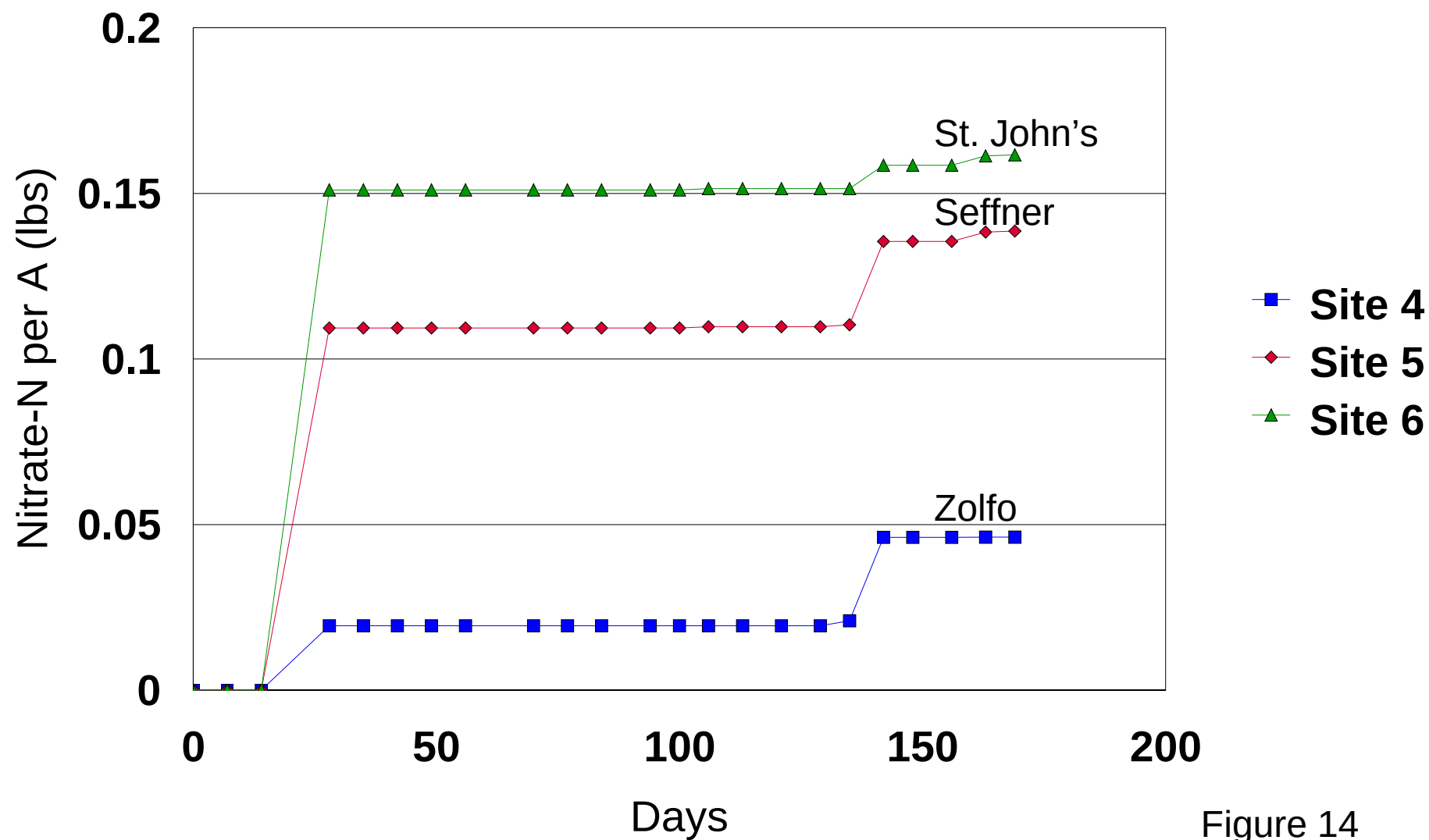


Figure 14

# Farm 3

## Site 7

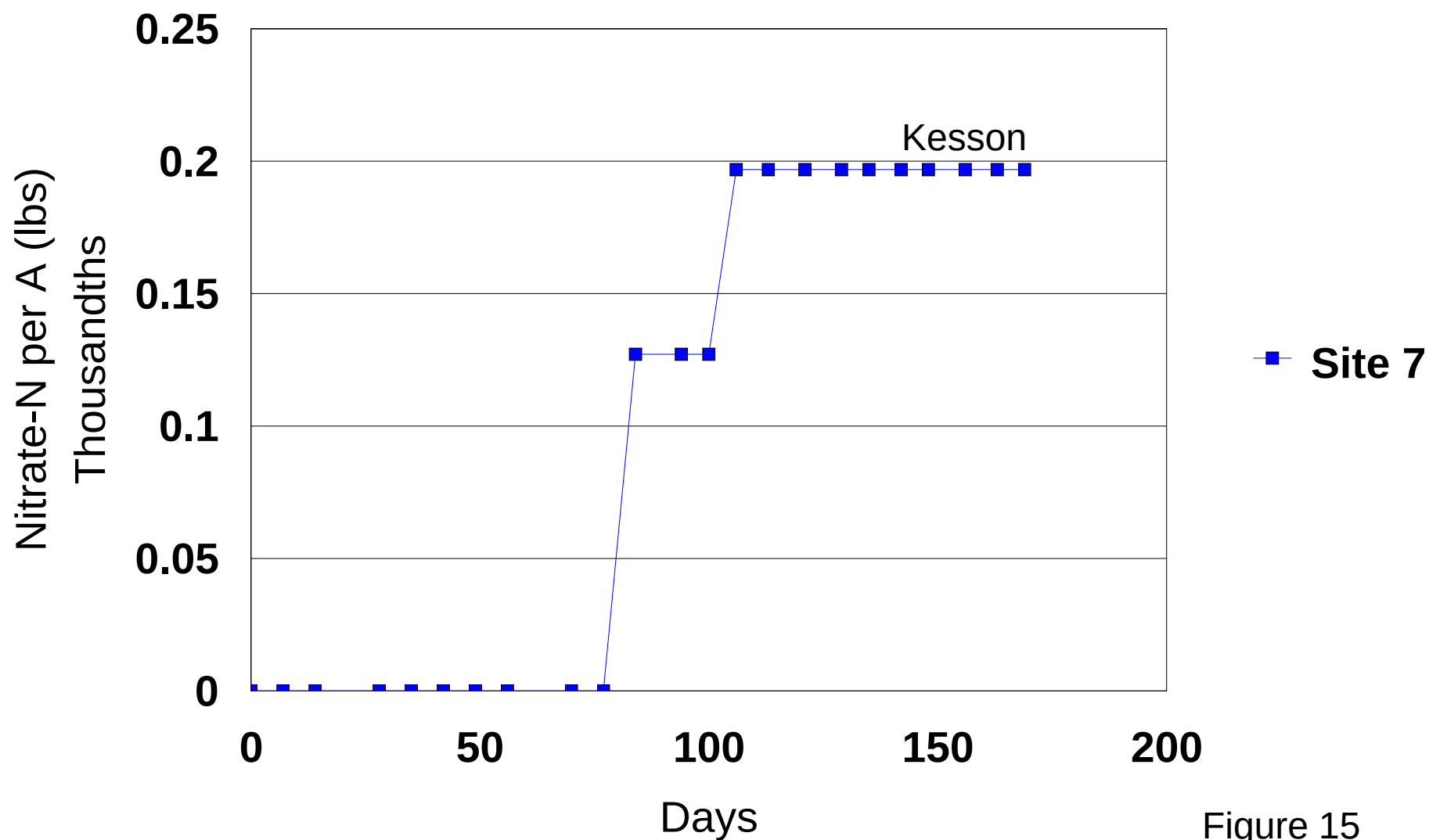


Figure 15

# Farm 4

## Site 8

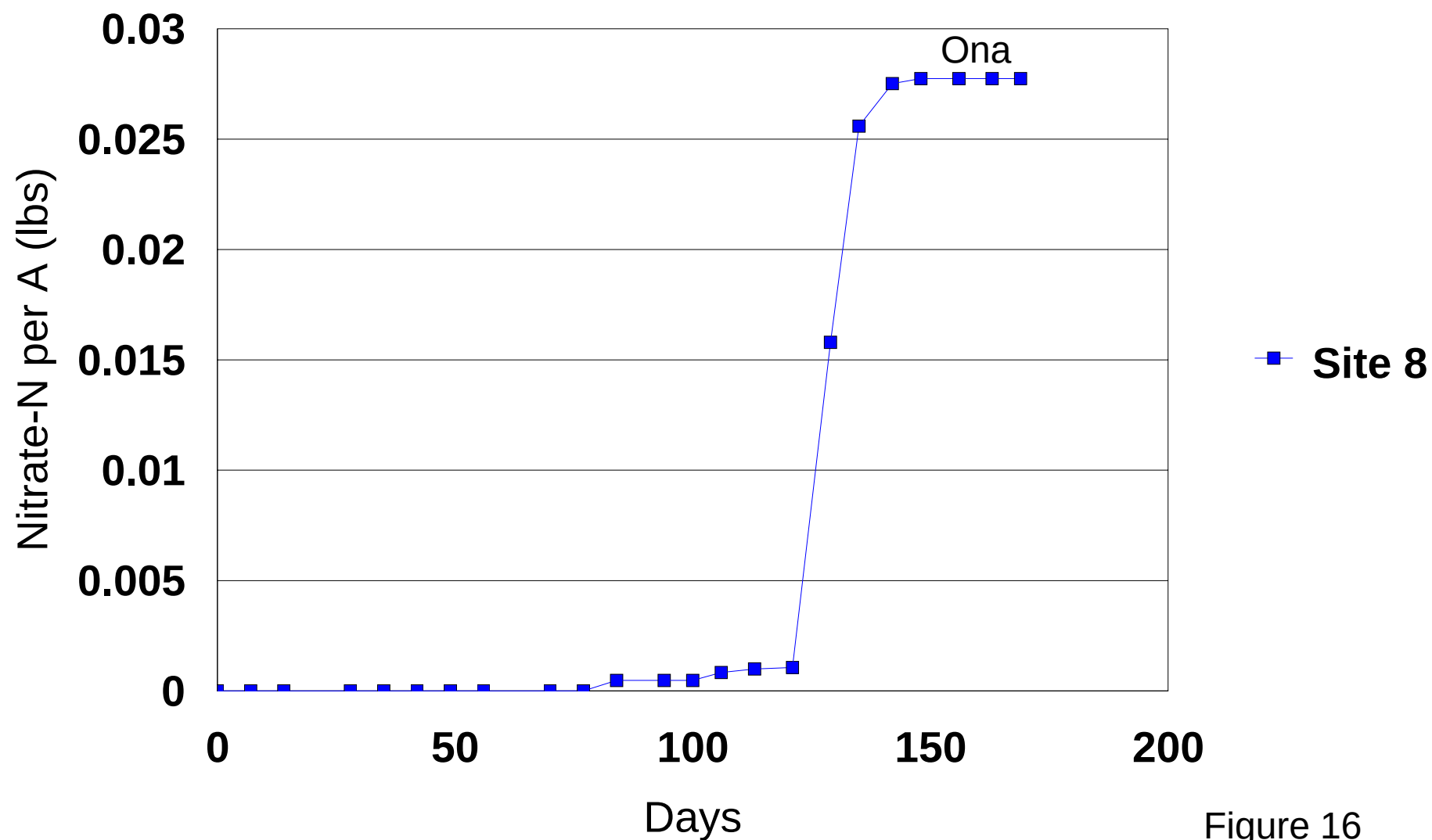


Figure 16

# Farm 5

## Site 9

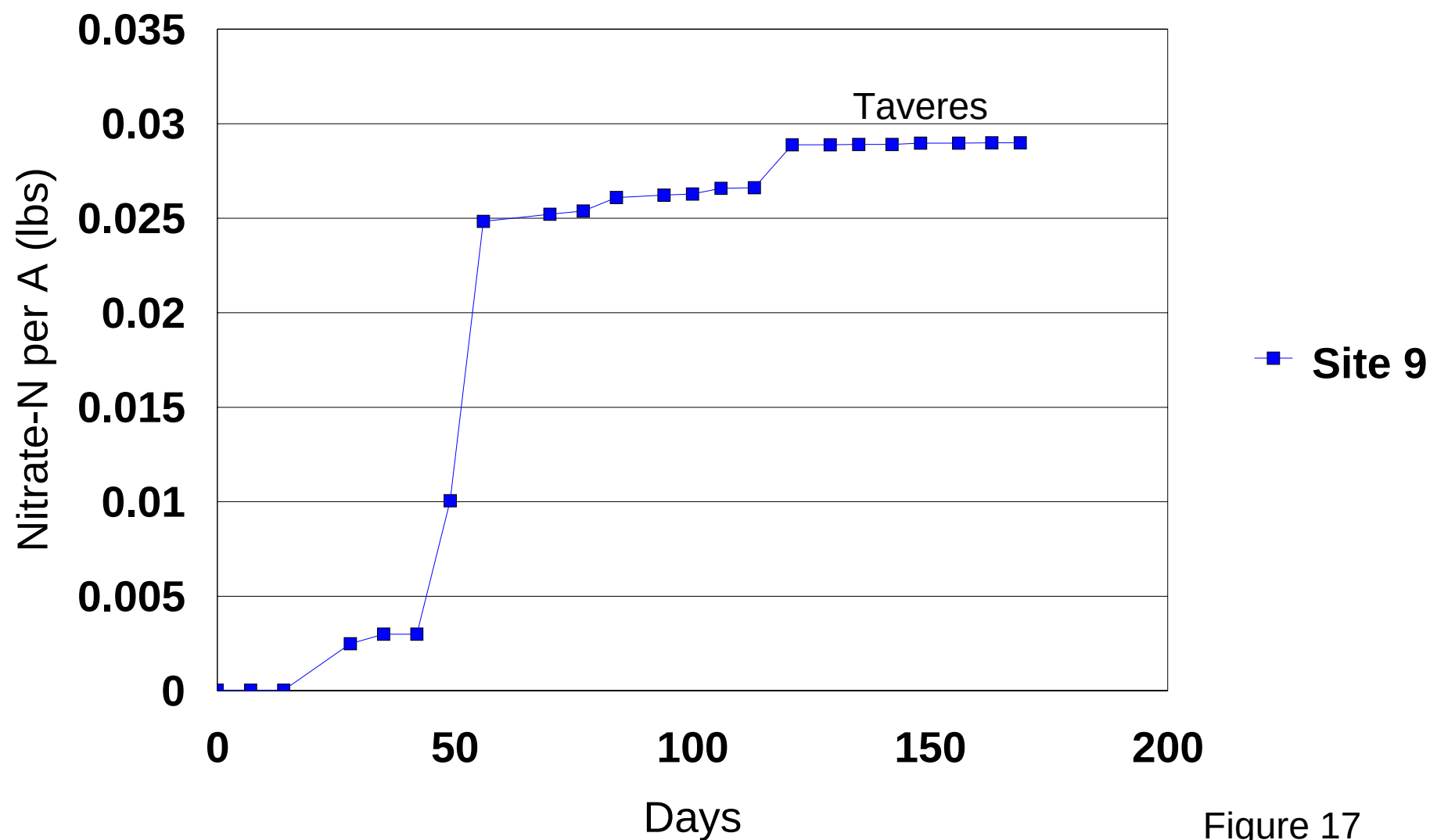


Figure 17

# Farm 6

## Site 10

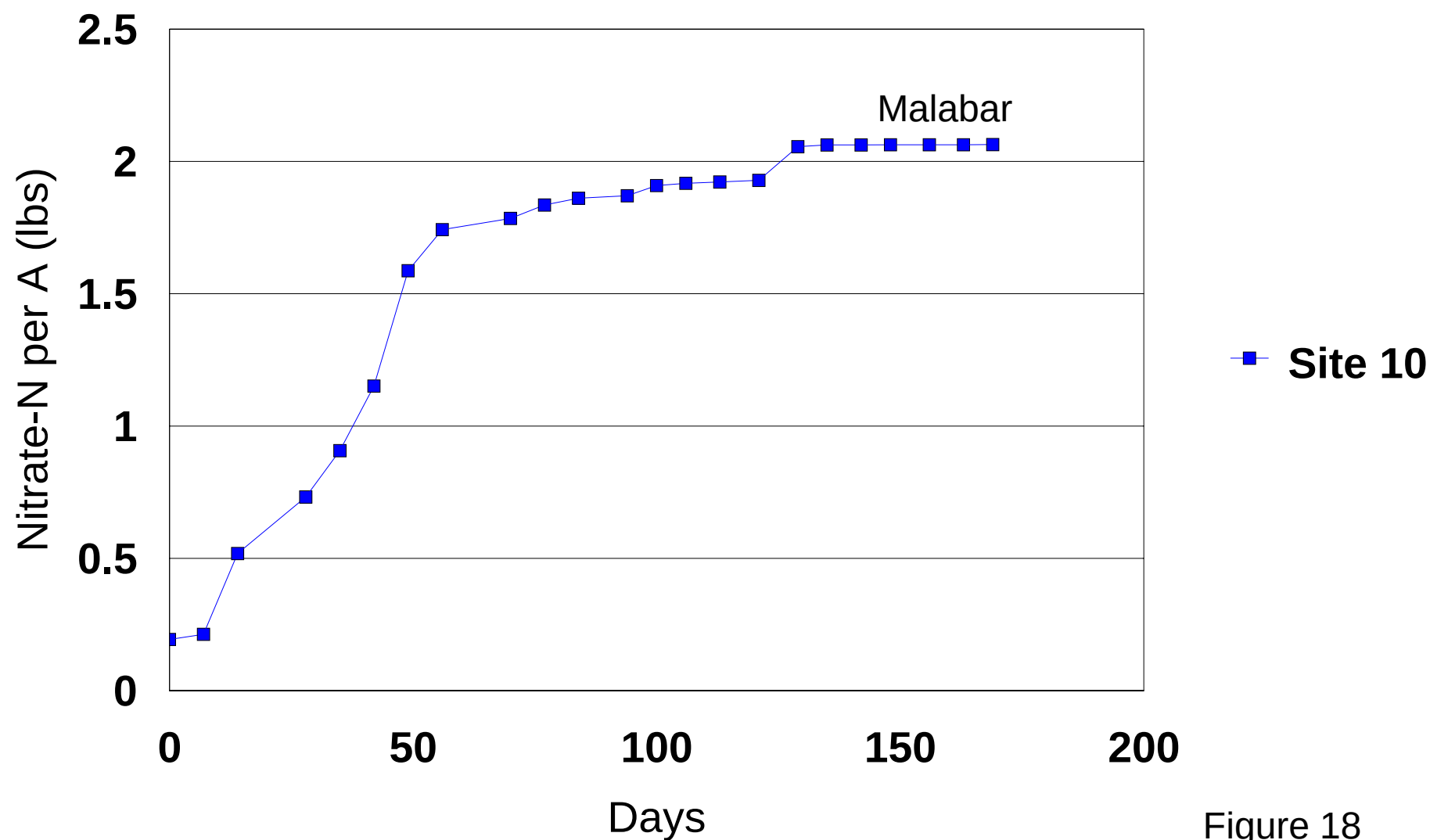


Figure 18

# Farm 7

## Sites 11, 12, and 13

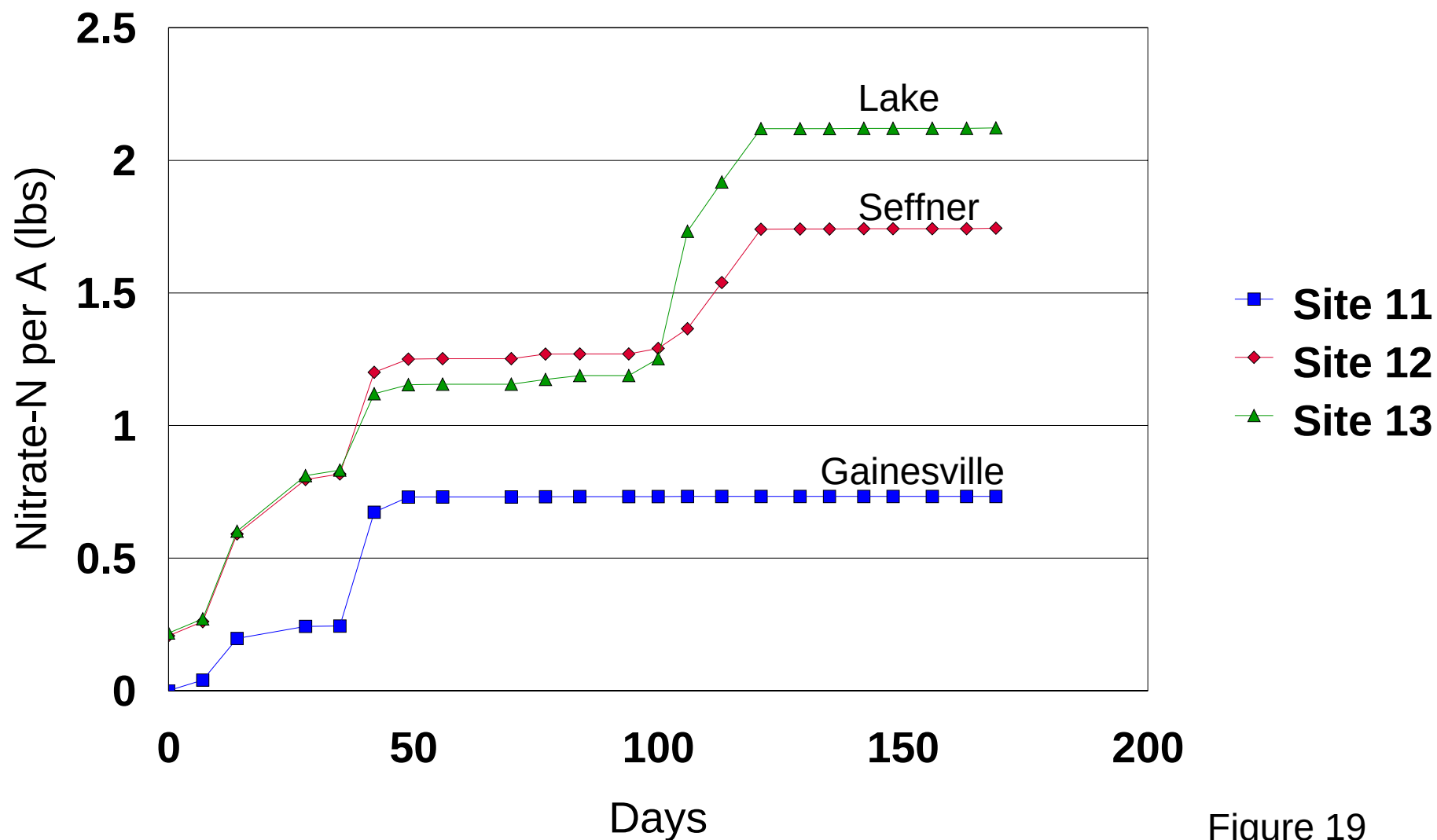


Figure 19

# Farm 8

## Site 14

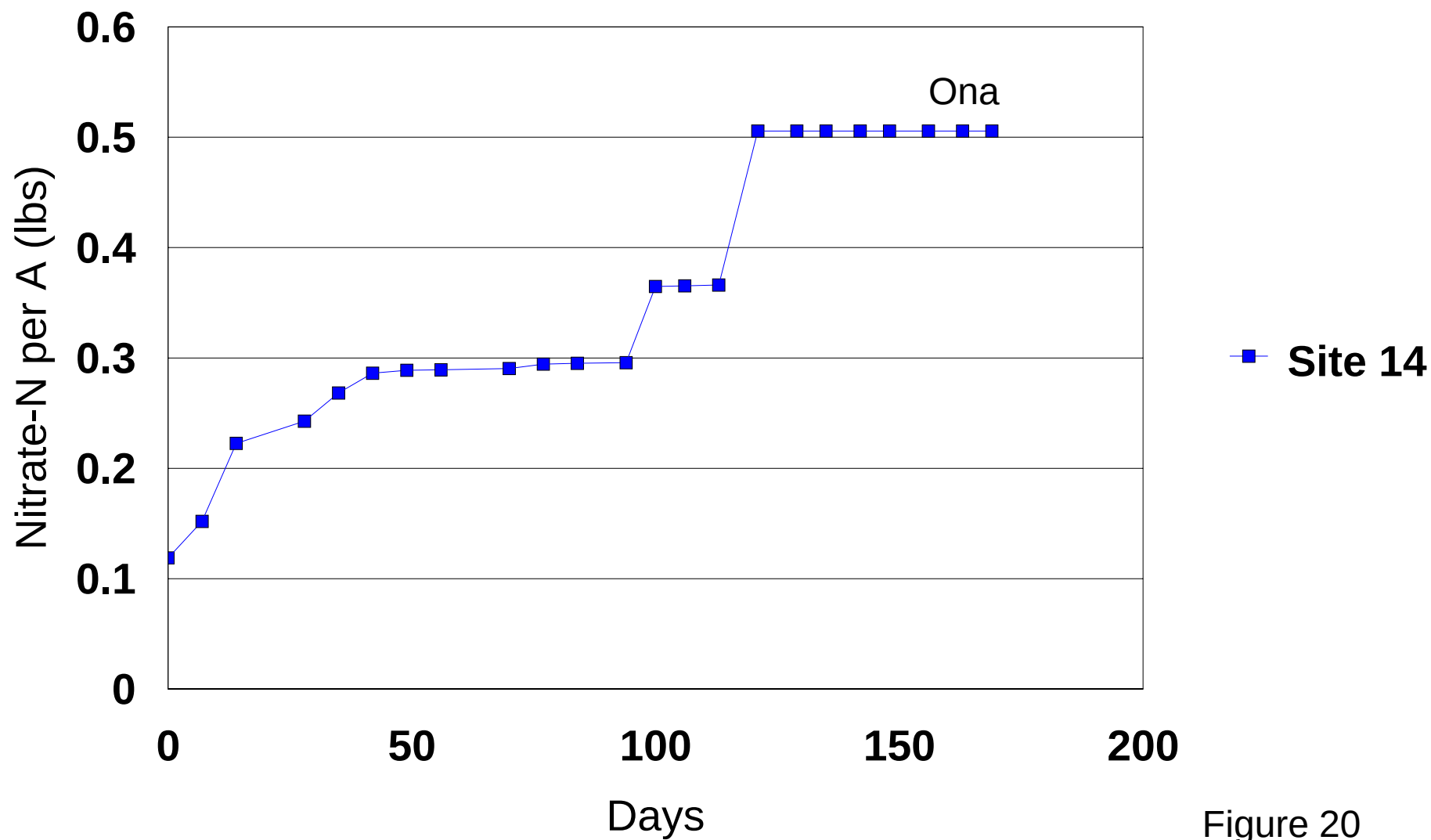


Figure 20

## Farm 9 Sites 15 and 16

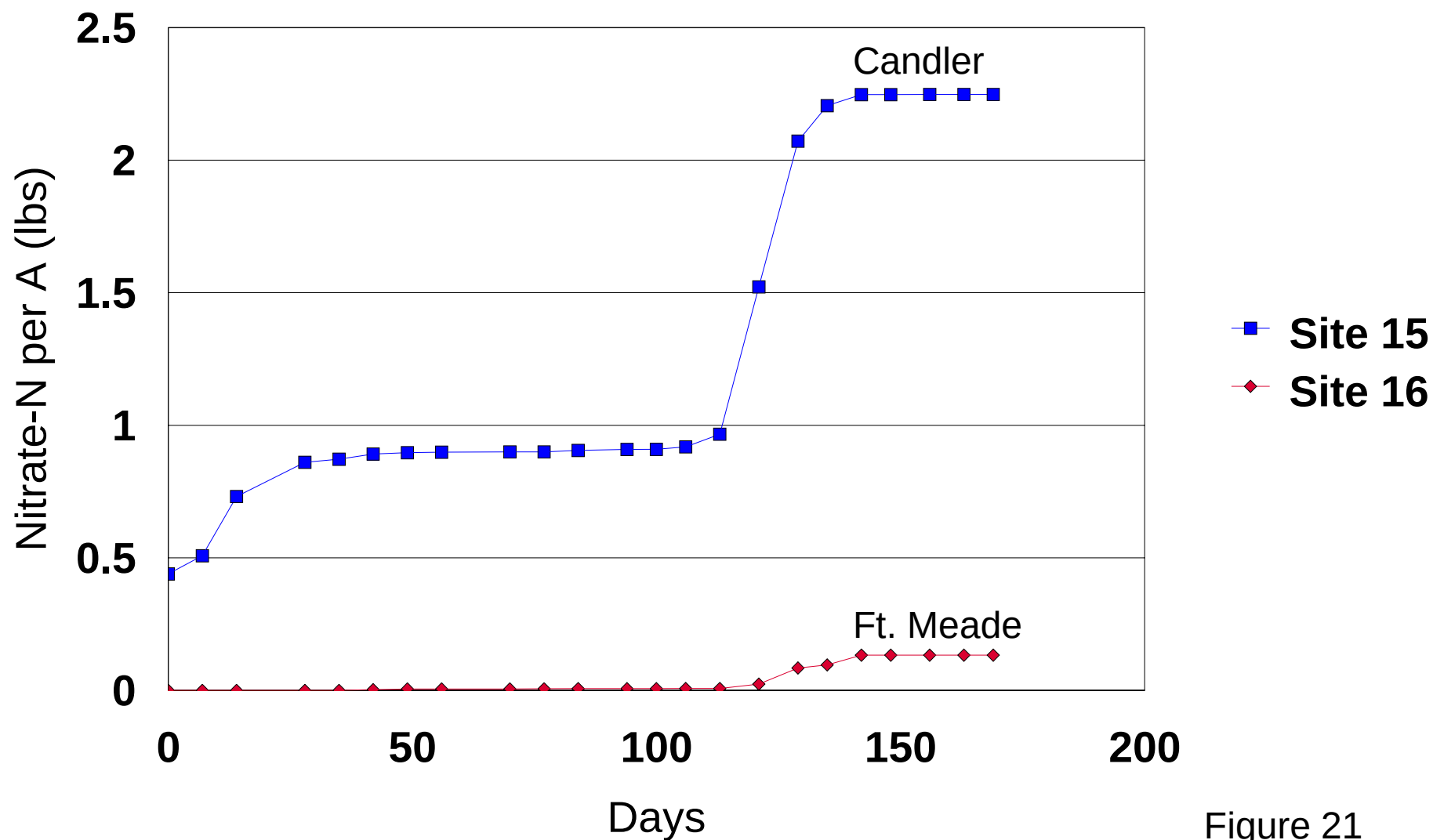


Figure 21

# Farm 10

## Sites 17, 18, and 19

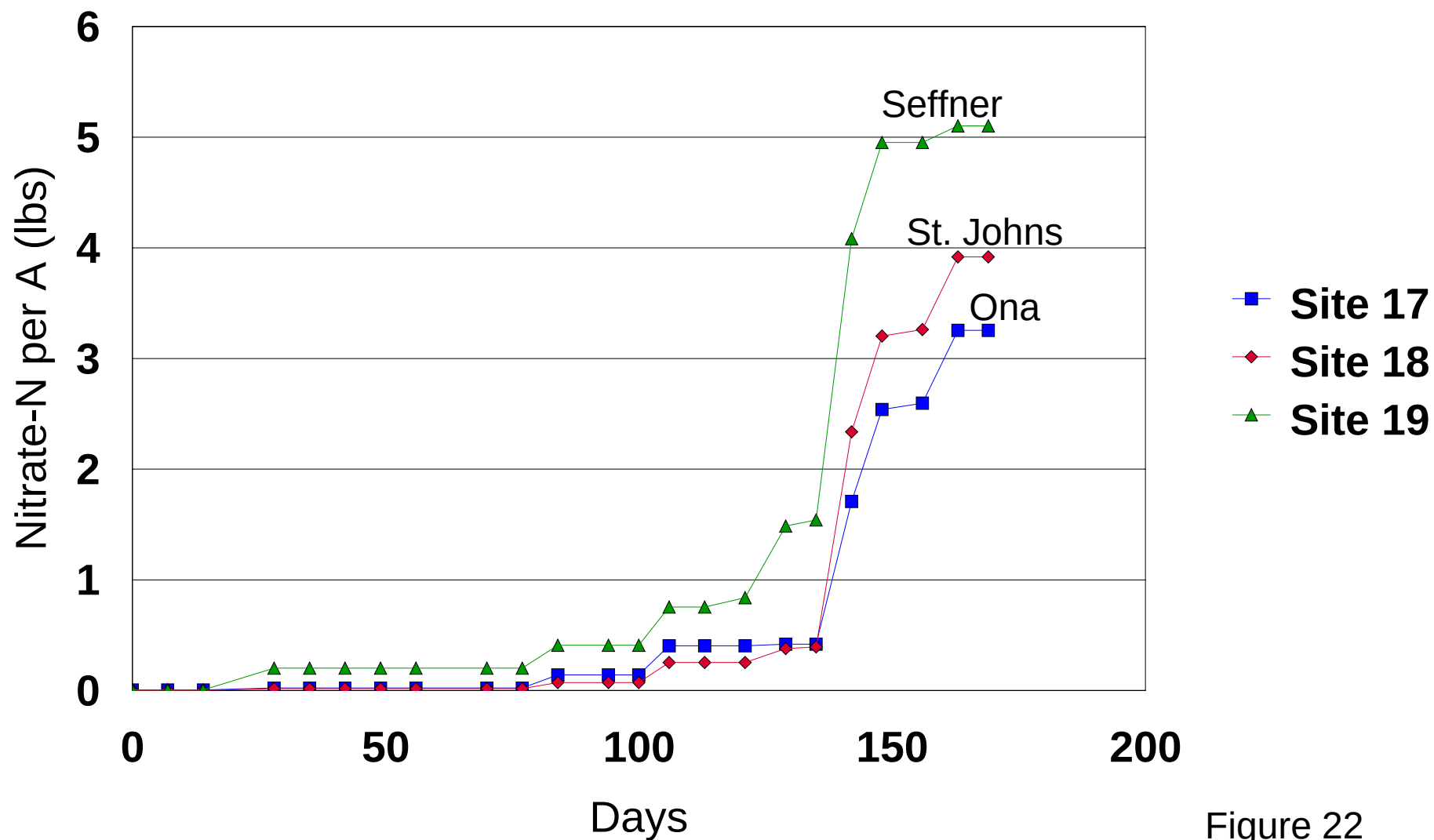


Figure 22

# Farm 11

## Site 20

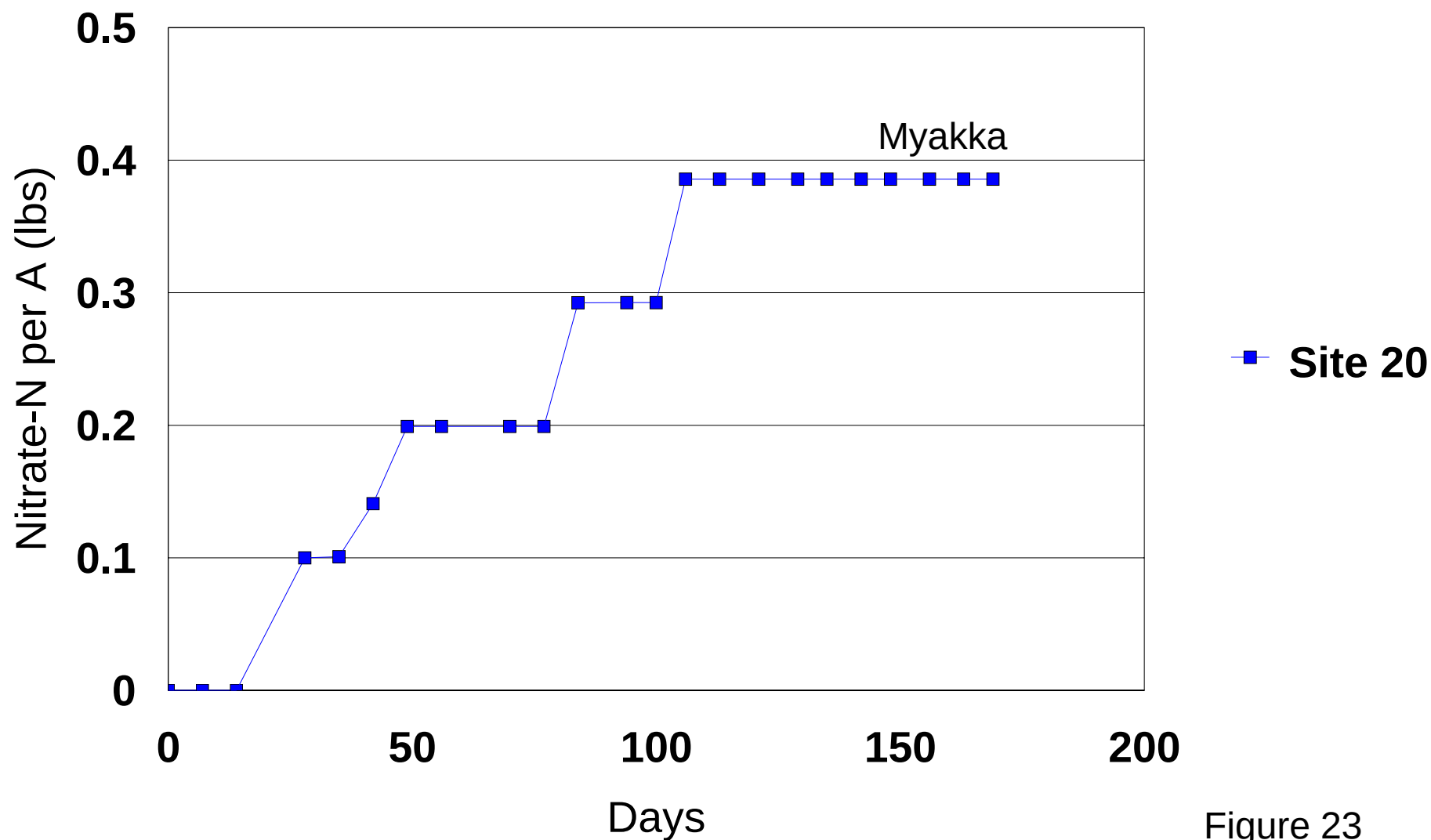


Figure 23

# All Sites

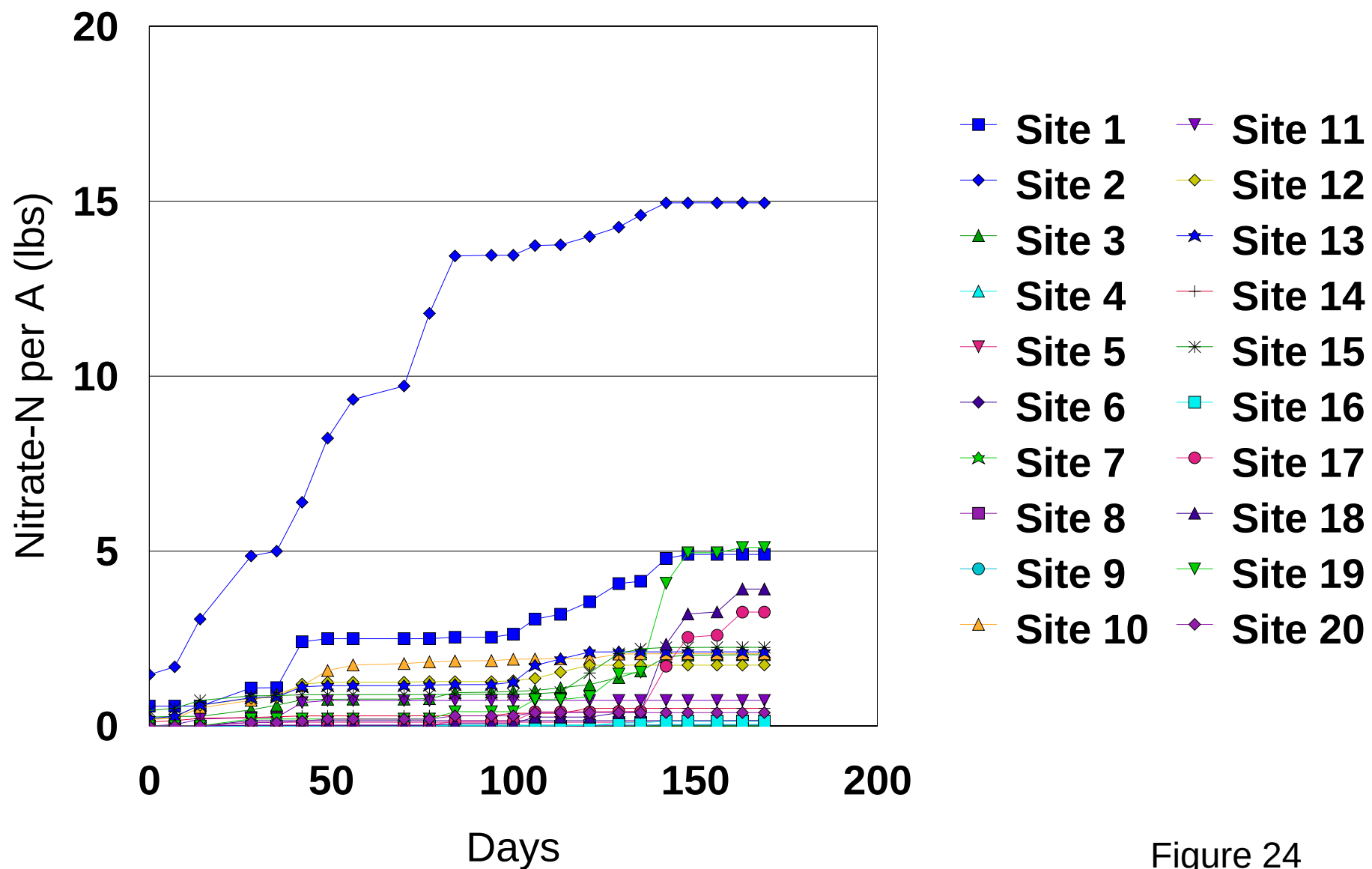


Figure 24

## 2005-2006 Progress Report

This is the annual progress report for Year 2 of the project. Overall, all the objectives that were planned were met for the second year of this study. It was initiated in August 2005, by re-identifying existing grower/cooperators who:

- 1) had production fields containing specific soil types
- 2) were willing to share specific cultural management information
- 3) would allow water quality samples to be collected from production fields on a weekly basis.

Sampling sites more than doubled from the 2004-05 season and cooperative agreements were arranged with grower/cooperators and monitoring equipment were installed. Figures 1-12 (2004-05 season section) show the sampling locations by farm overlaid on an aerial photo and soil map. A modified shorter design of the passive wick sampler (to facilitate easier and less destructive installation procedure) was used and compared at each sampling site. Figure 13 (2004-05 section) shows a cross-sectional diagram of the original sampler which uses fiberglass rope to break tension in soil column and cause accumulated water to move into the collection chamber. The leached water is then collected by suctioning out through the access tube and subsequently analyzed for nitrate-N content. Figure 25 shows the high degree to which the sampler has shown to be effective on different soils, but particularly effective on sandy soils. A detailed description for the operational theory for the sampler can be found at: [http://www.regional.org.au/au/asssi/supersoil2004/s15/oral/1627\\_geeg.htm](http://www.regional.org.au/au/asssi/supersoil2004/s15/oral/1627_geeg.htm).

A weekly water sampling scheme for strawberry production was implemented in November 2005 and continued through March 2006. Once strawberry production ceased, sampling continued at those locations where a double crop (i.e. melons, peppers, etc) was planted to follow the strawberries through May. As resulted from a survey of cooperators, generally, for a projected 120-day strawberry crop, producers were applying 0 to 30 lbs N as dry pre-plant fertilizer and 0.75-1.5 lbs N applied as liquid fertilizer per day. Irrigation applications ranged from 45 min/day to 3 hr/day depending on emitter flow rate and grower preference. However the majority of producers were applying irrigation water at 60 min/day. Fertilizer was injected at mid- to late-irrigation cycle with enough time left to flush the system before the irrigation cycle concluded. Specifically, the following general conclusions resulted from the responses to the survey:

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- 6) ~ 50% of growers apply no dry pre-plant fertilizer
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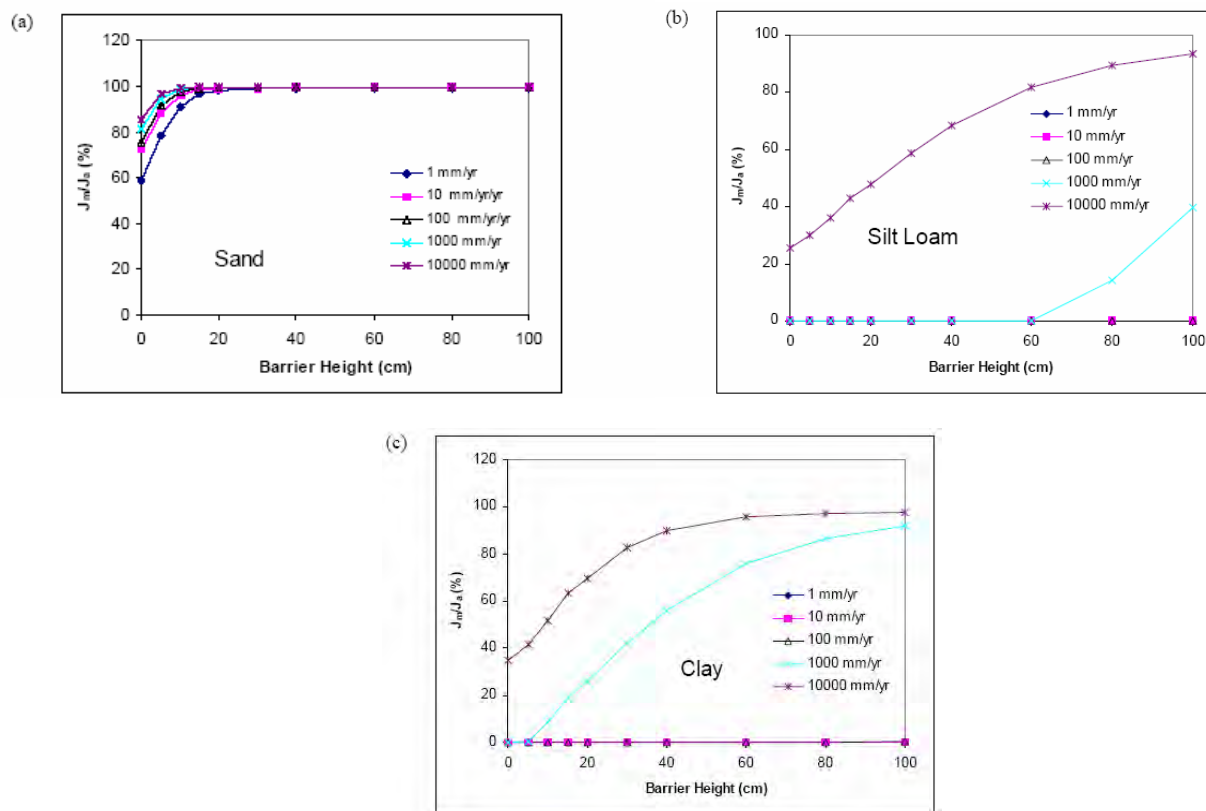
Soil types of the sites identified included Immokalee, Pomello, St. Johns, Seffner, Zolfo, Kesson, Ona, Taveres, Malabar, Lake, Gainesville, Candler, Fort Meade, and Myakka. All sites had dry season water table levels below 2 m, so the sampling procedures used the passive “wick”-type leachate collector. As stated earlier, a smaller collector was developed and evaluated. These collectors allowed for collection of water and nutrients leaching below the crop rooting zone and allowed an estimated of mass balance losses of N and water from the fields.

Figures 26-28 show the weekly losses for each sampling site at each farm. Remarkably, the results are very similar to the 2004-2005 results for specific farms. The results show that for the vast majority of sites, less than one lb/week was being leached with very few exceptions. Figure 29 show the seasonal weekly losses for all sampling sites. These figures support the minimal weekly leaching that was occurring at all grower/cooperator locations.

The modified sampler that was used this season was used in addition to the original samplers, thus, each sampling site had 8 samplers. Figures 30-32 show the comparison of samplers. A statistical analysis to compared the samplers' performance showed no difference for the sampling season.

Seasonal cumulative nitrate-N losses for each site (with soil identified) at each farm are shown in Figures 33 through 44 (scales for each figure may differ). The figures show that for seasonal accumulated leaching losses of nitrate-N, only Farm 1 had losses exceeding 5 lbs/A and most were 2 lbs/A or less. Assuming a total seasonal application of 150 lbs/A, less than 10% losses occurred. Figure 45 summarizes the seasonal cumulative results for all sites. When compared to Figure 46 (2004-2005 cumulative results) it is remarkably evident that consistent and effective water and nutrient management practices are being used by the participants in the study and they seem to be doing an exceptional job of minimizing water and nutrient losses during the production season. Information from this first year of data collection was presented at the Florida Strawberry Growers Association's Agritech 2006 meeting.

These results are so consistent with the 2004-2005 results that very few modifications to existing practices are warranted. Although the results reflect the practices of the project participants only, this information is extremely valuable to the industry as a whole and provides evidence that grower participation in the state's BMP implementation program should be encouraged and will involve very few modifications to existing practices.



Water flux efficiency ratios ( $J_m/J_a$ ) for 3a) sand, 3b) silt loam, and 3c) clay soils under a variety of steady-flux conditions and diversion barrier heights (Gee et al. 2004. SuperSoil 2004: 3rd Australian New Zealand Soils Conference, 5 – 9 December 2004, University of Sydney, Australia.)

Figure 25

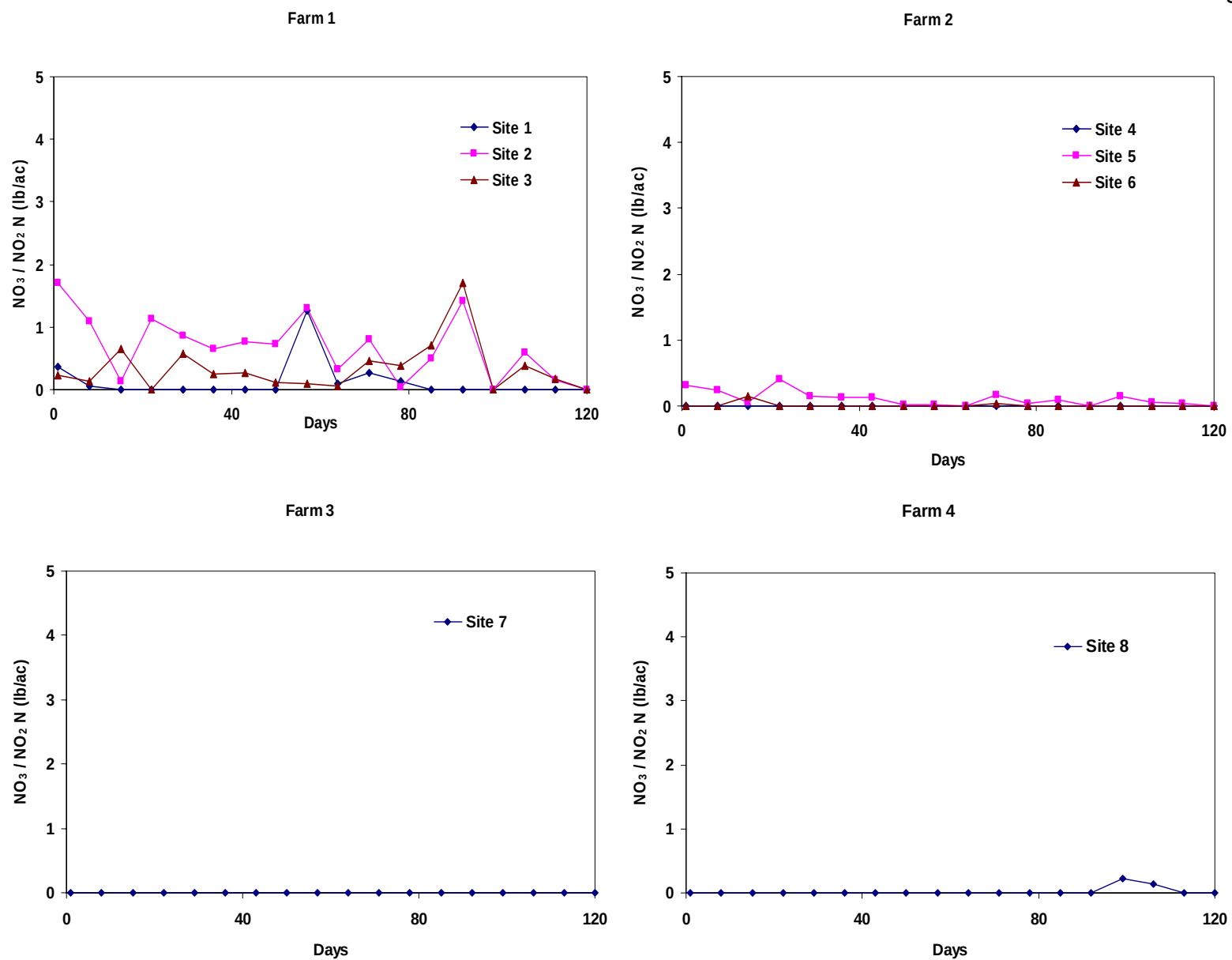


Figure 26

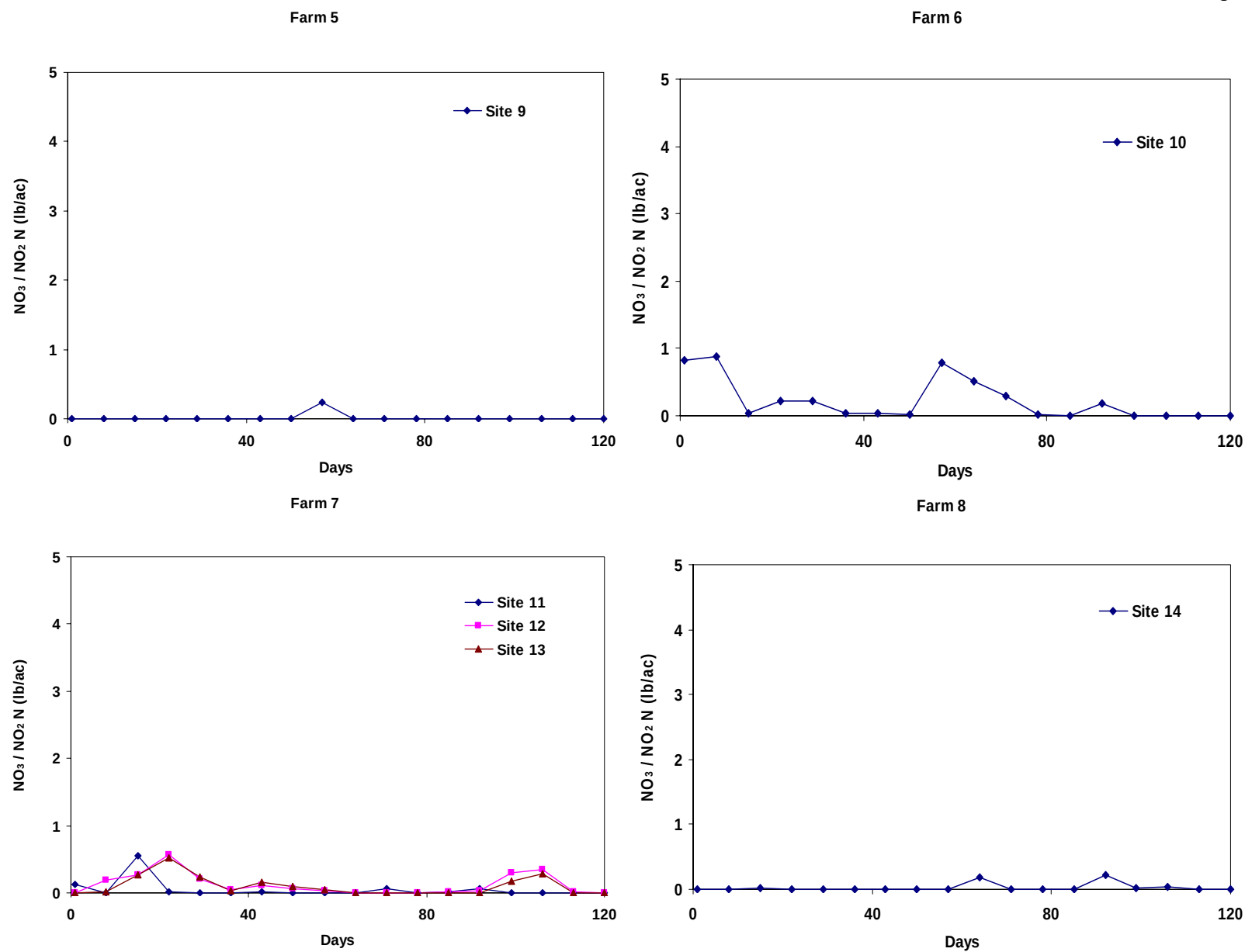


Figure 27

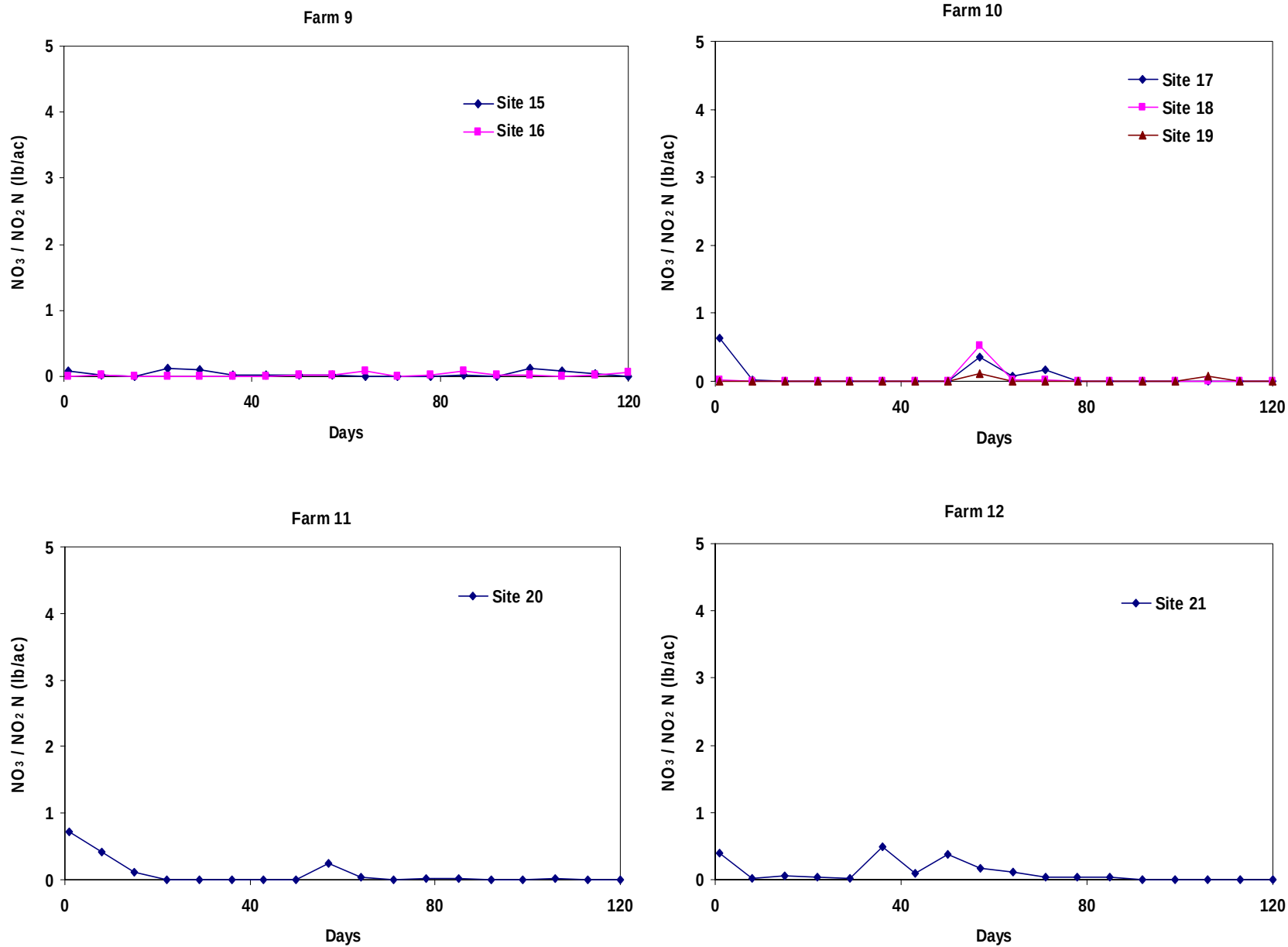


Figure 28

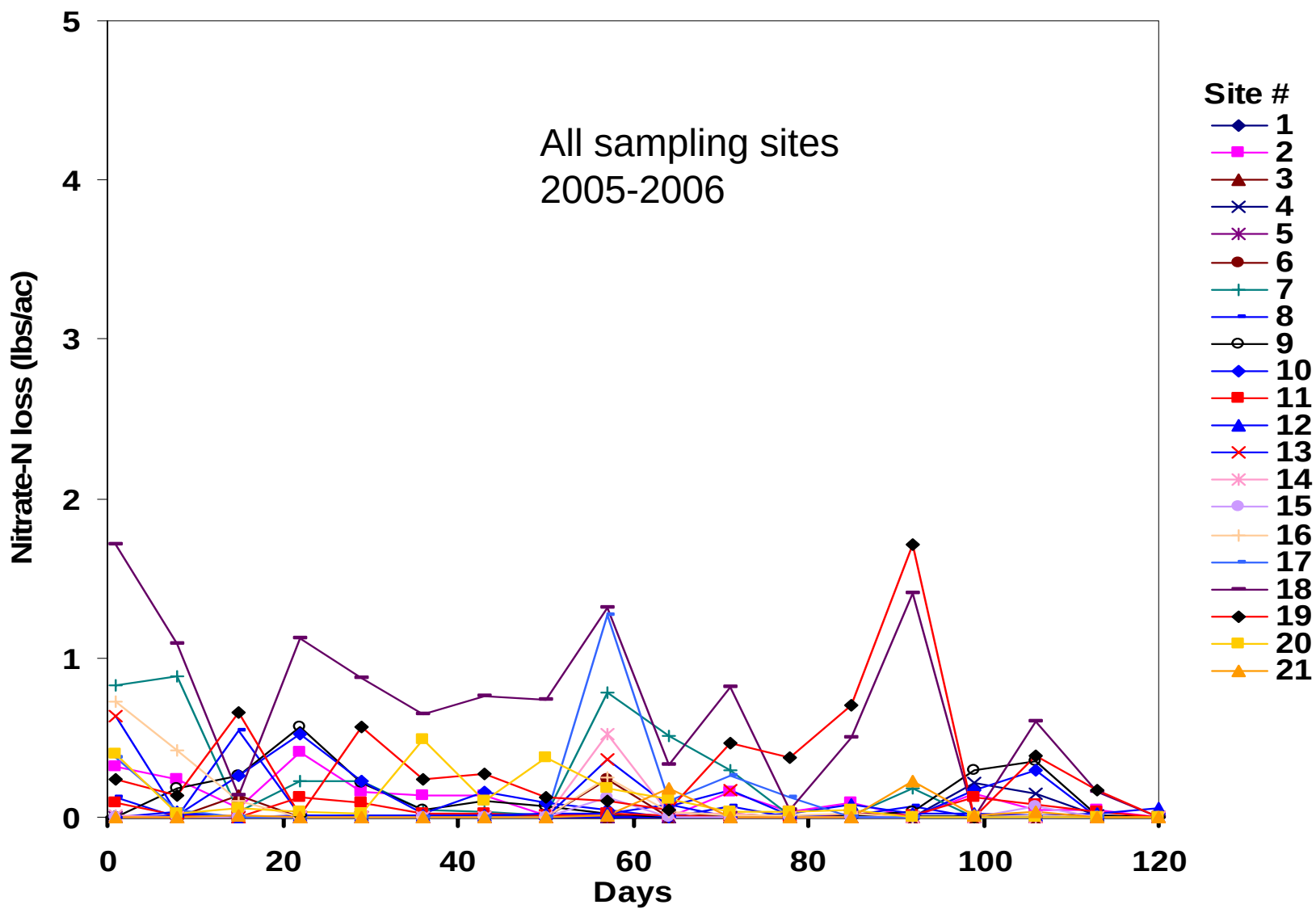


Figure 29

## Comparison of performance of large samplers to small samplers

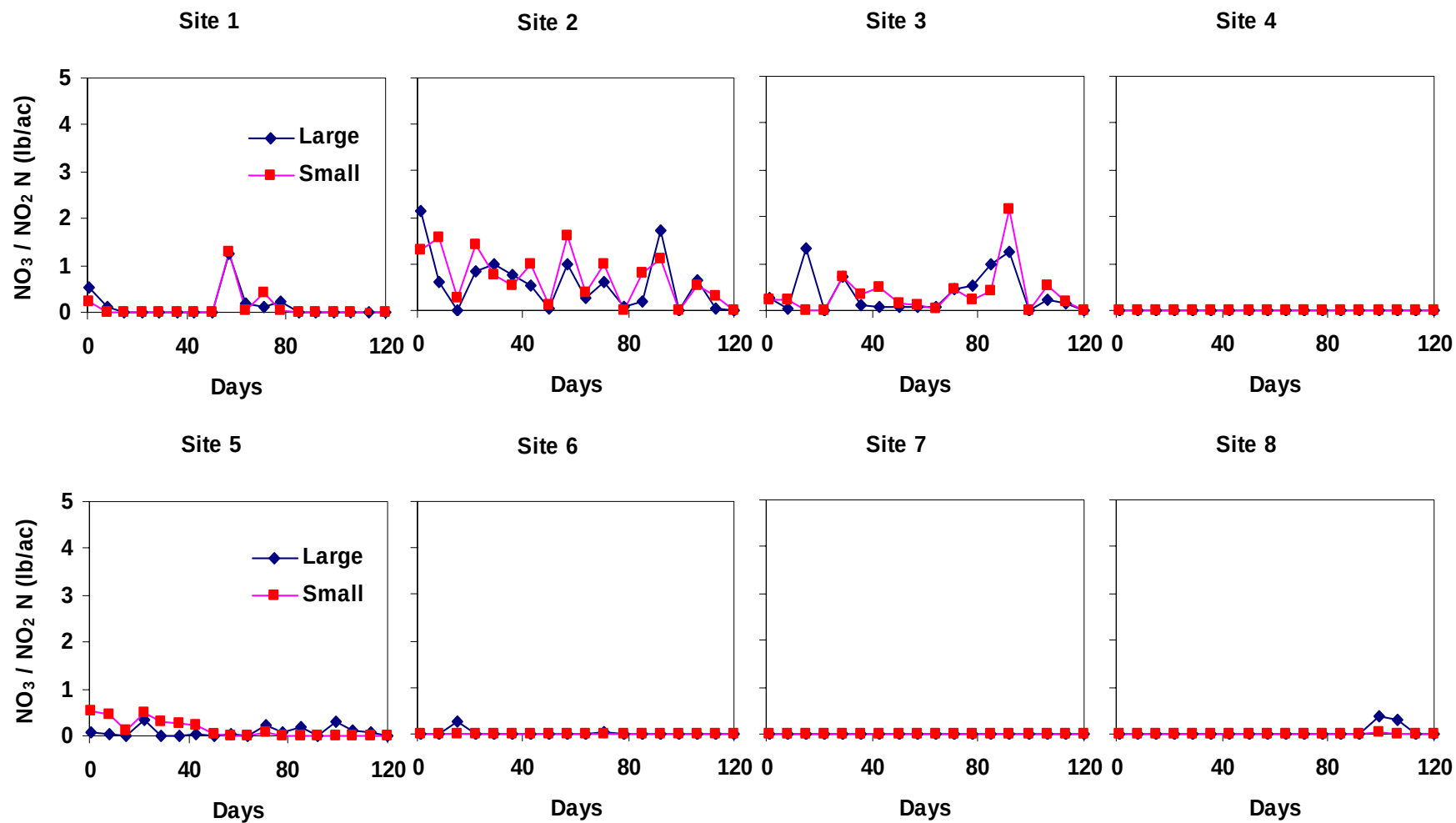


Figure 30

## Comparison of performance of large samplers to small samplers

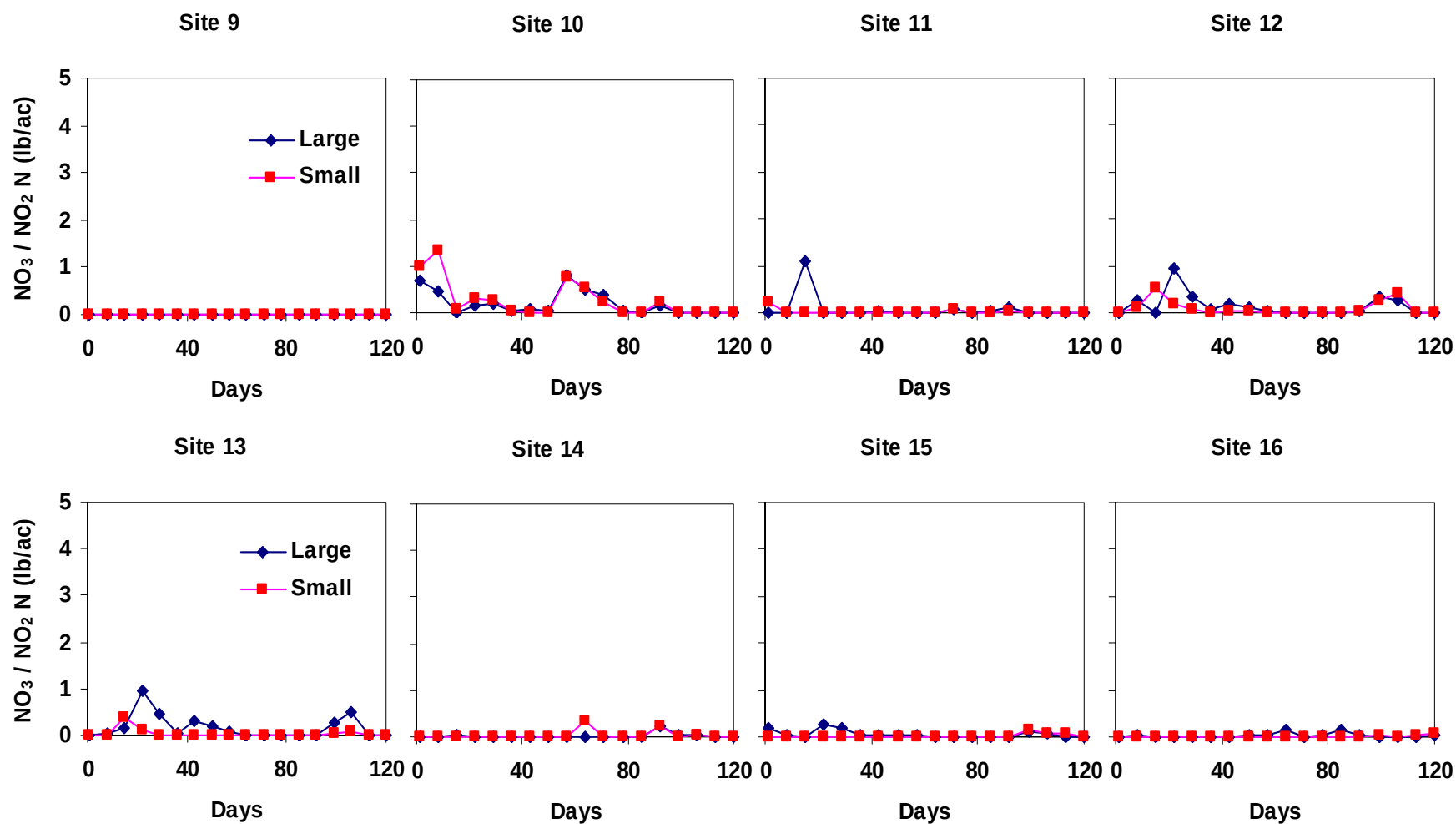


Figure 31

## Comparison of performance of large samplers to small samplers

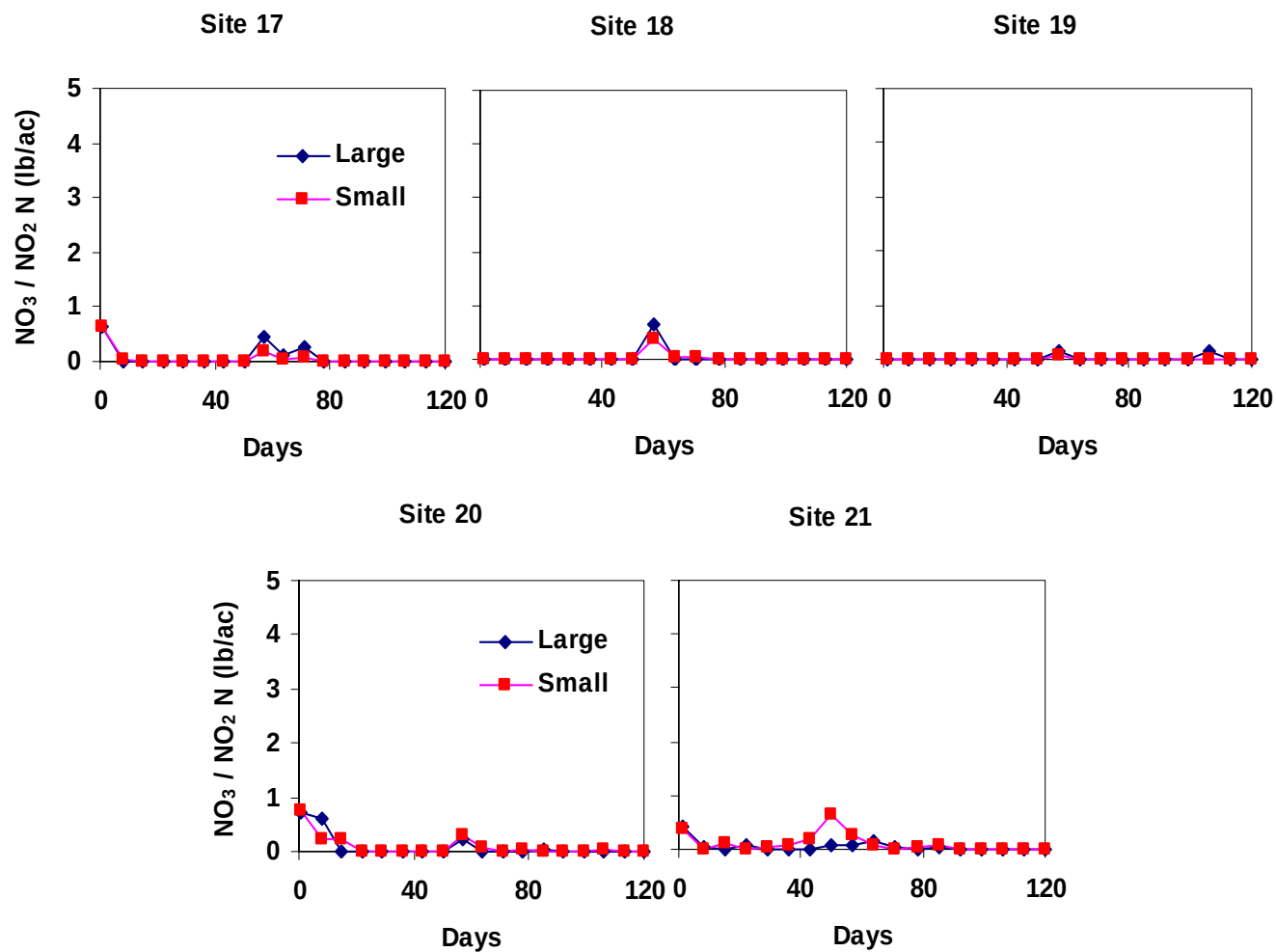


Figure 32

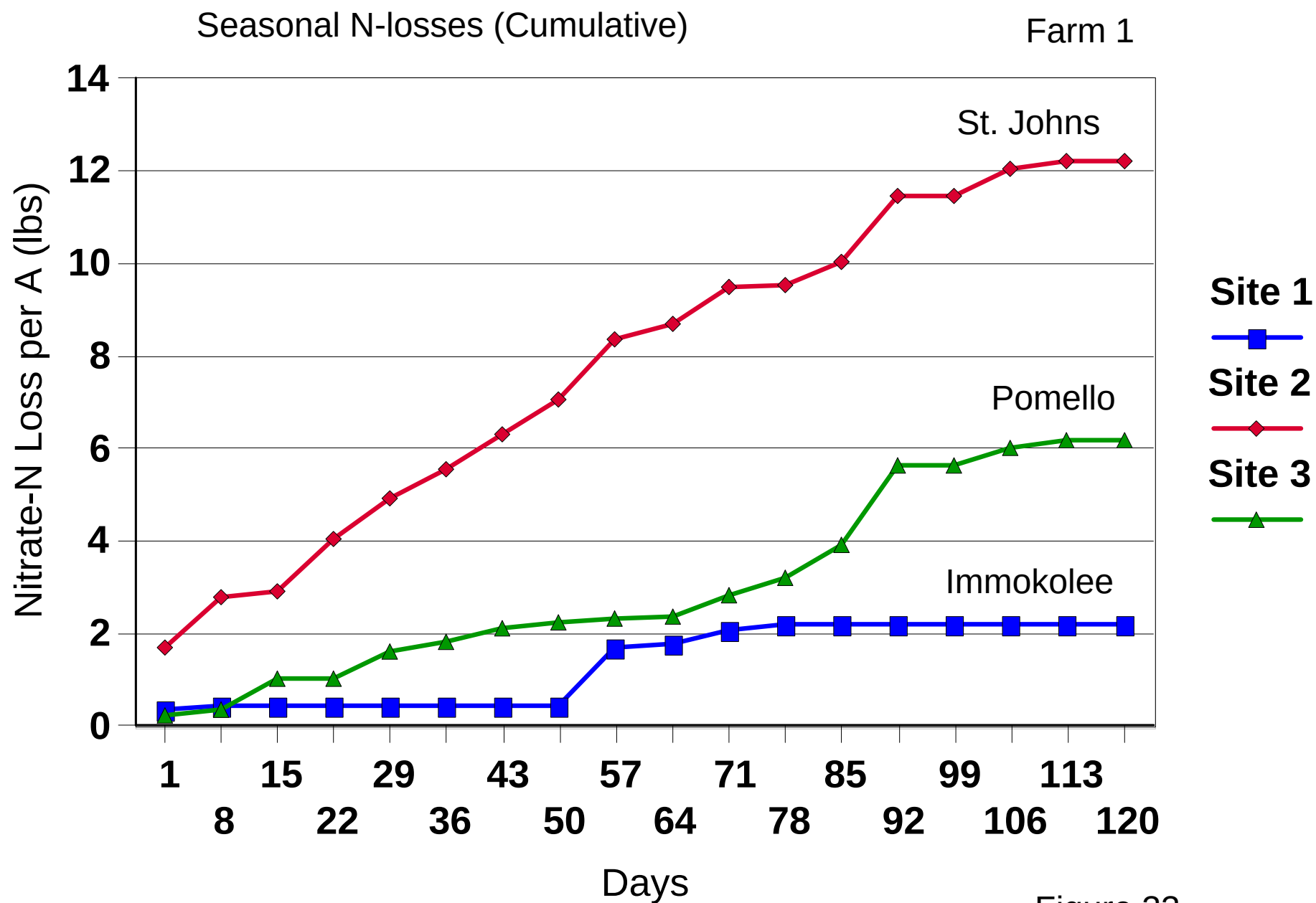


Figure 33

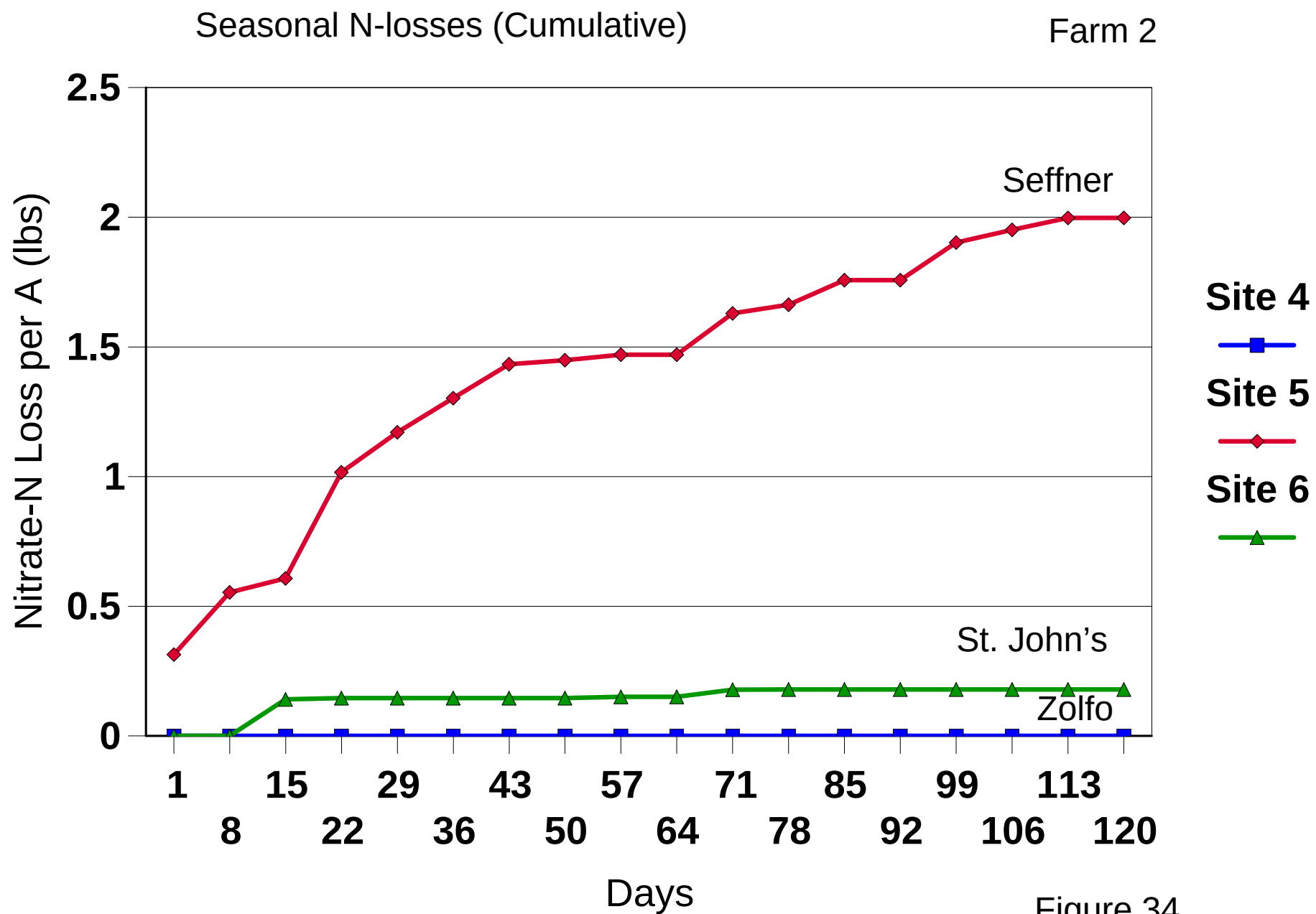


Figure 34

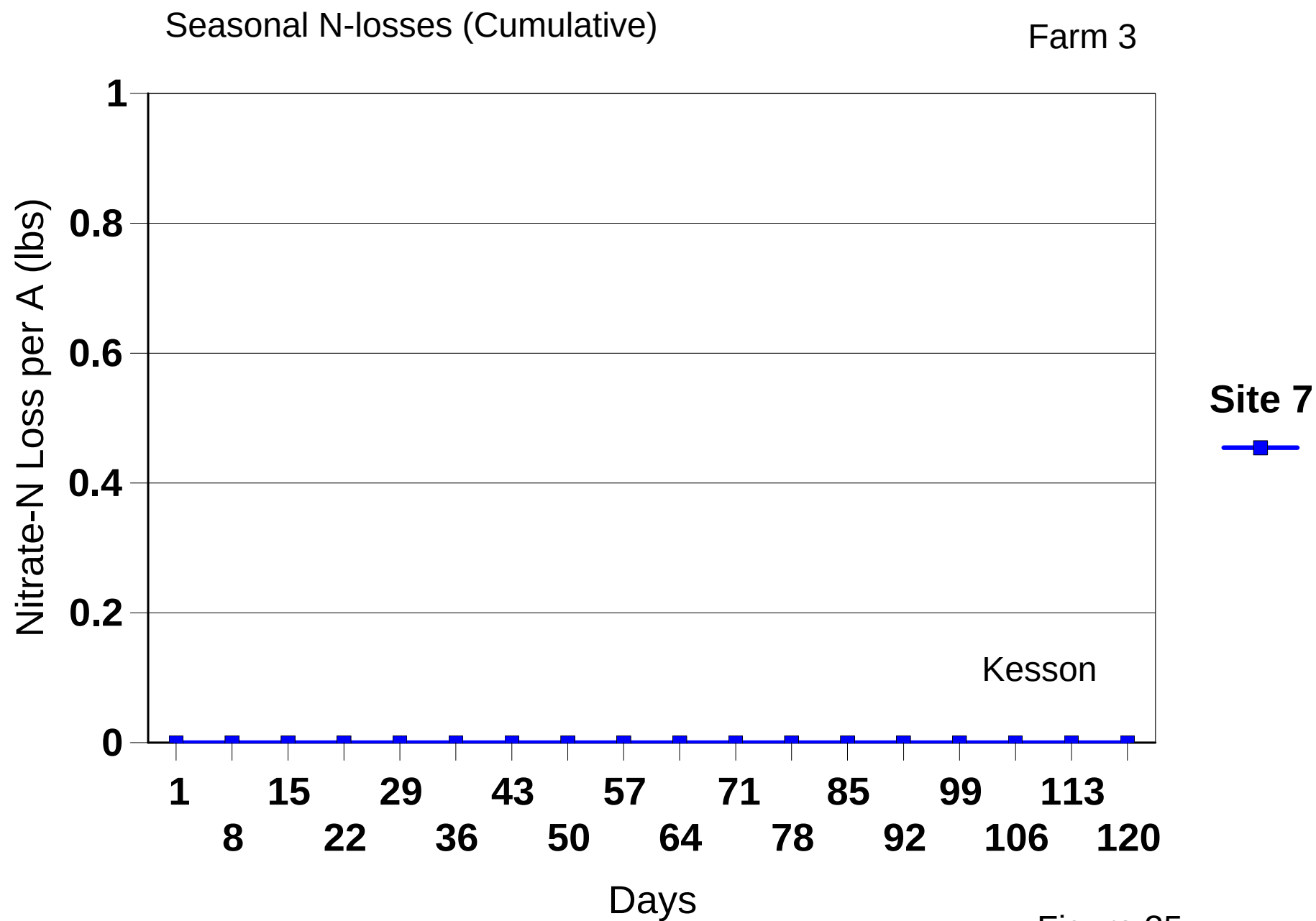


Figure 35

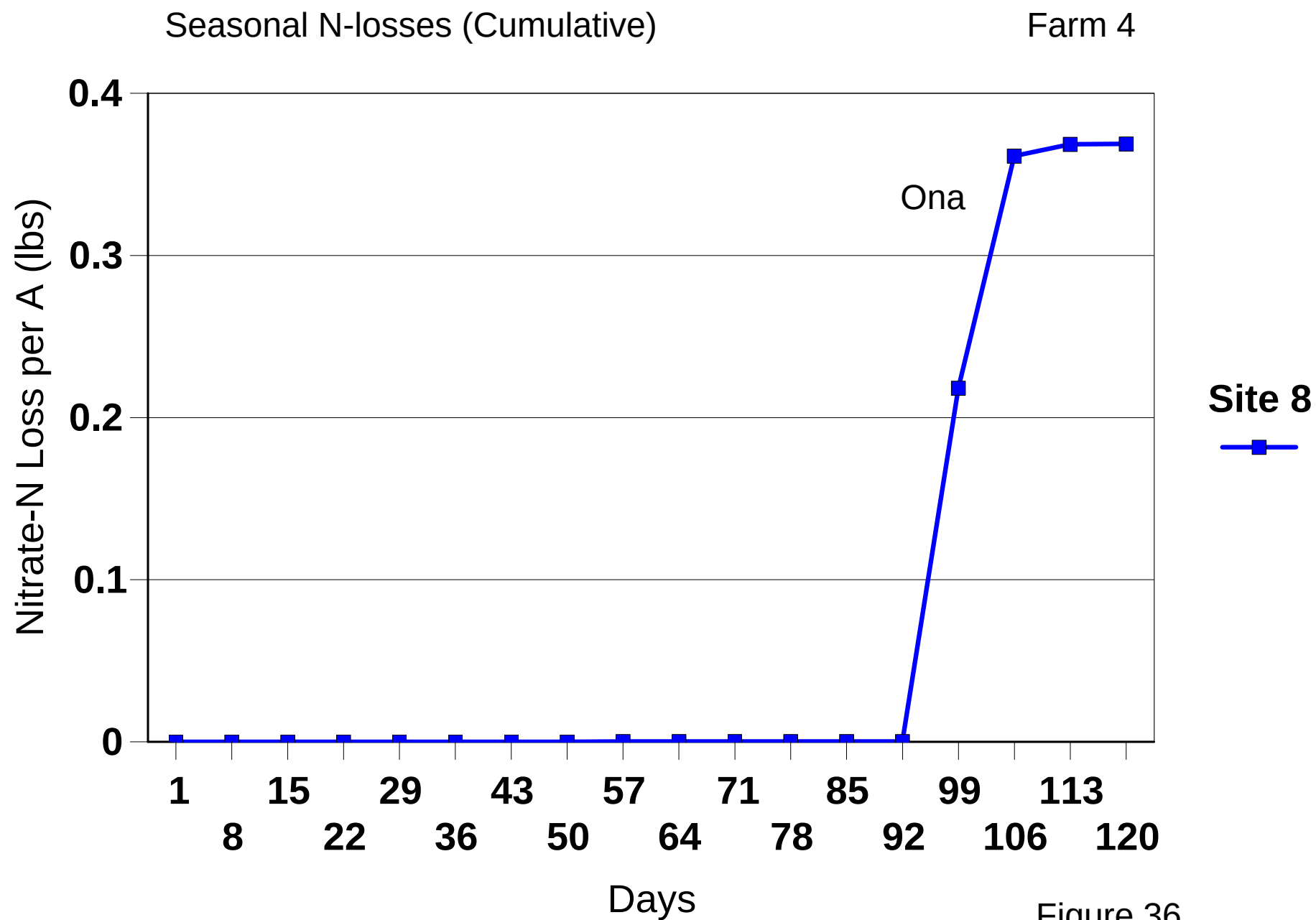


Figure 36

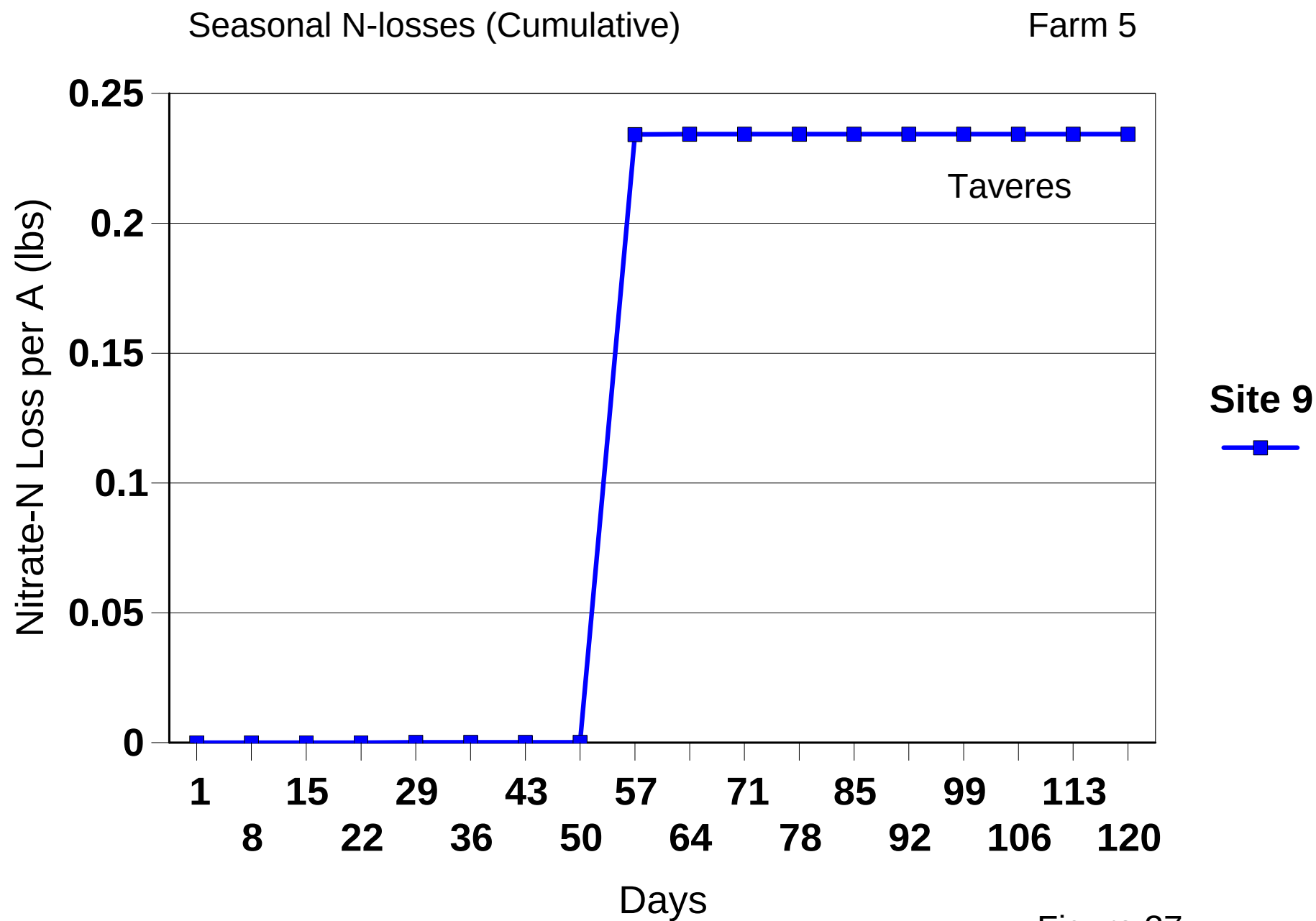


Figure 37

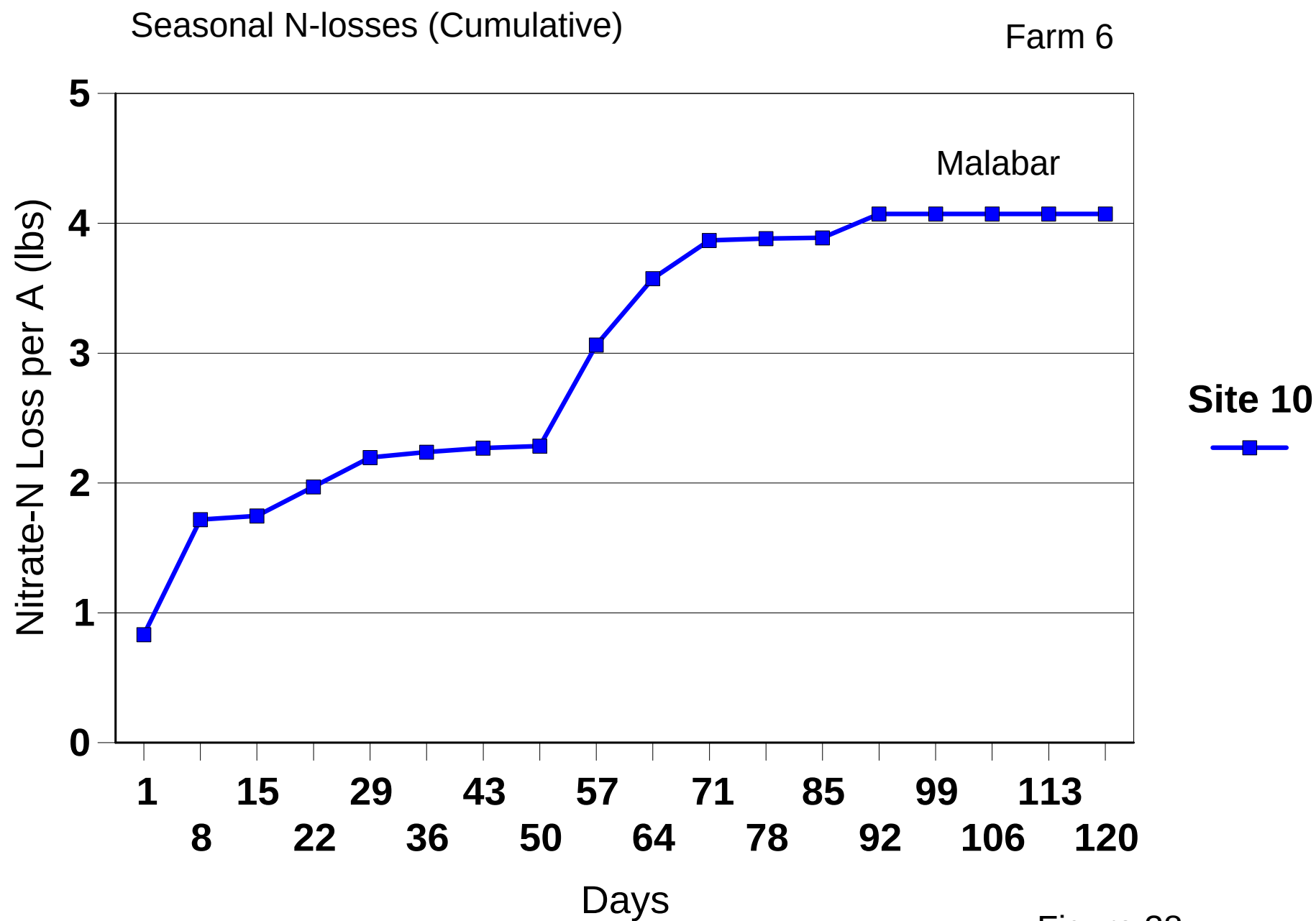


Figure 38

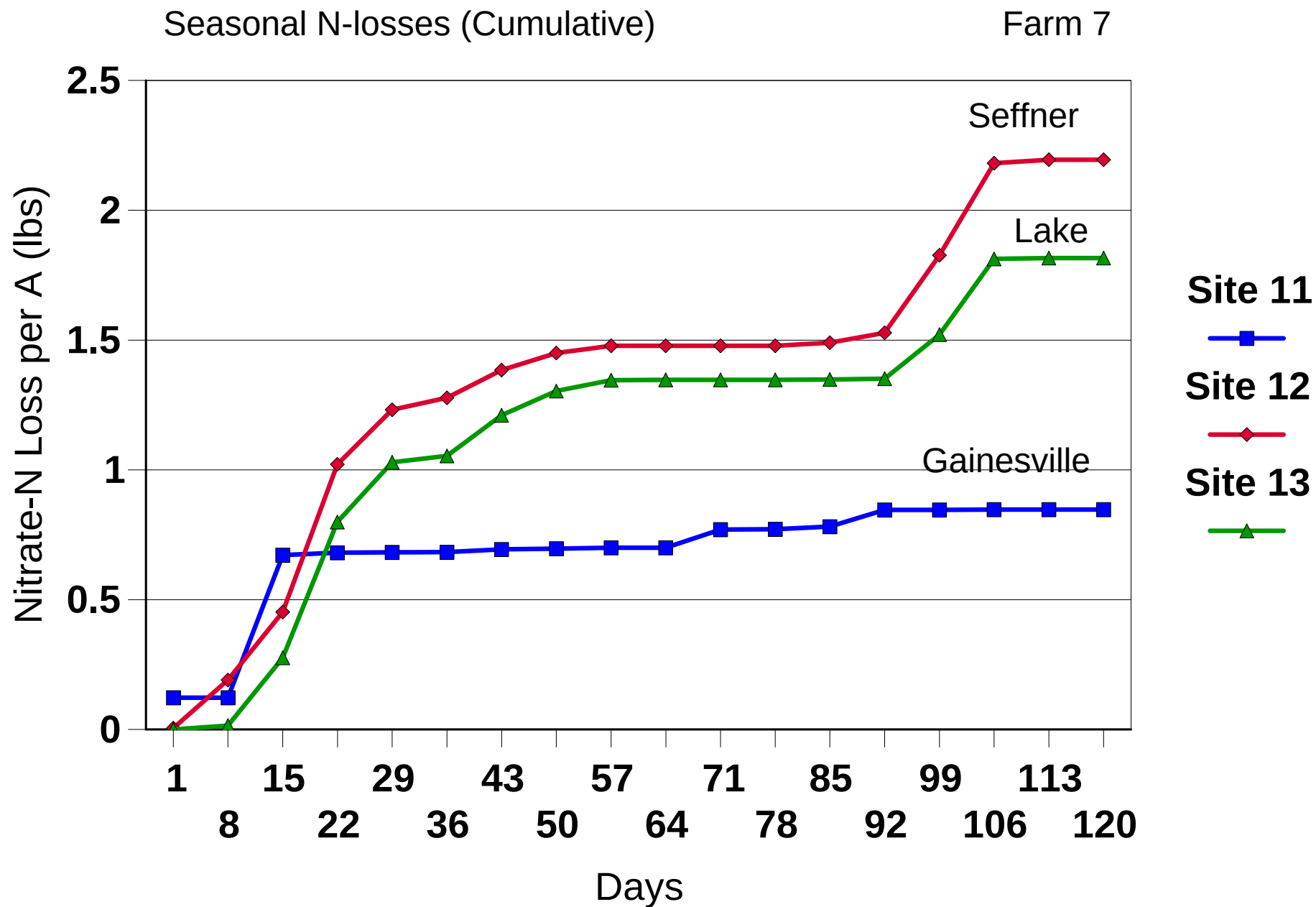


Figure 39

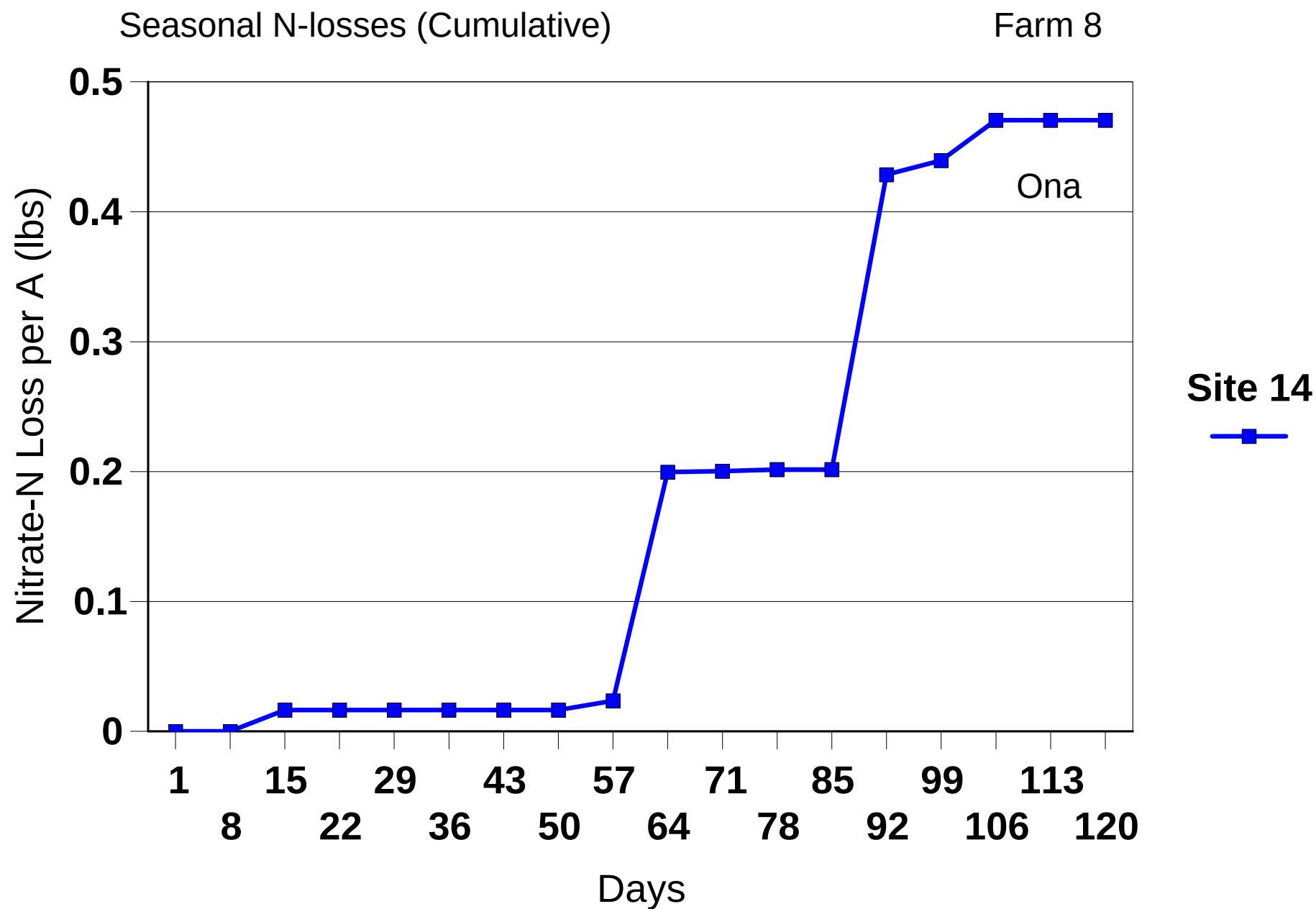


Figure 40

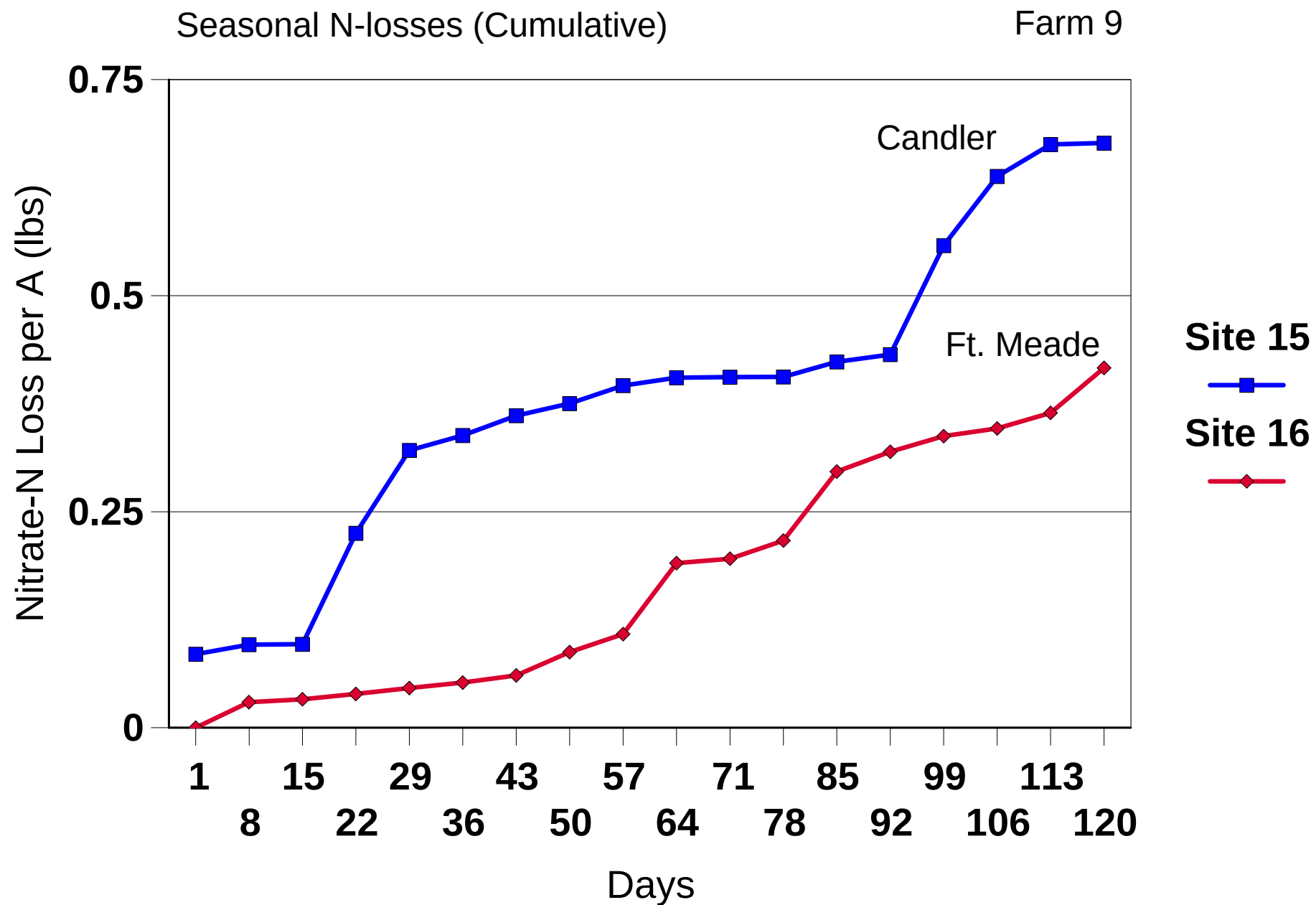


Figure 41

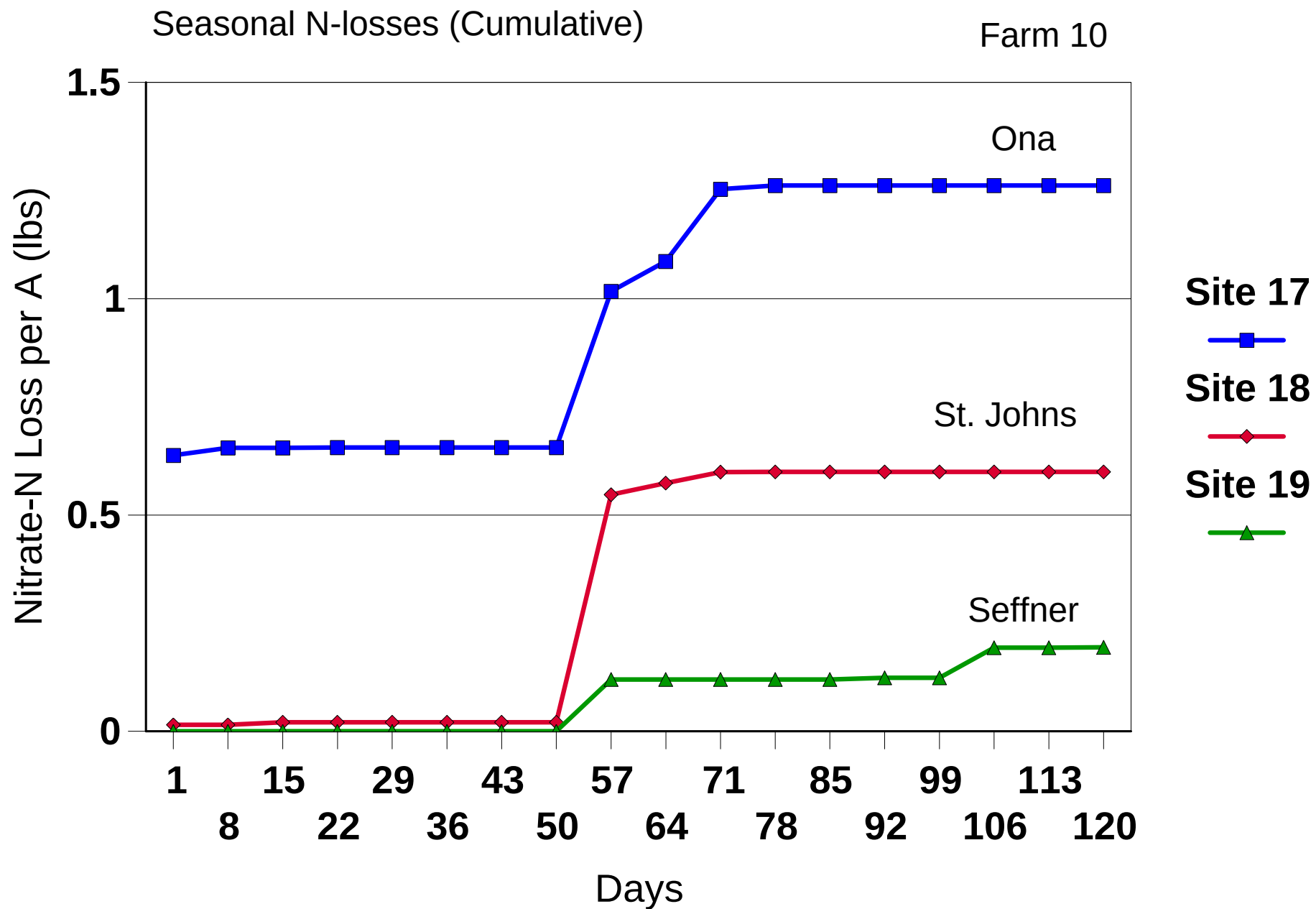


Figure 42

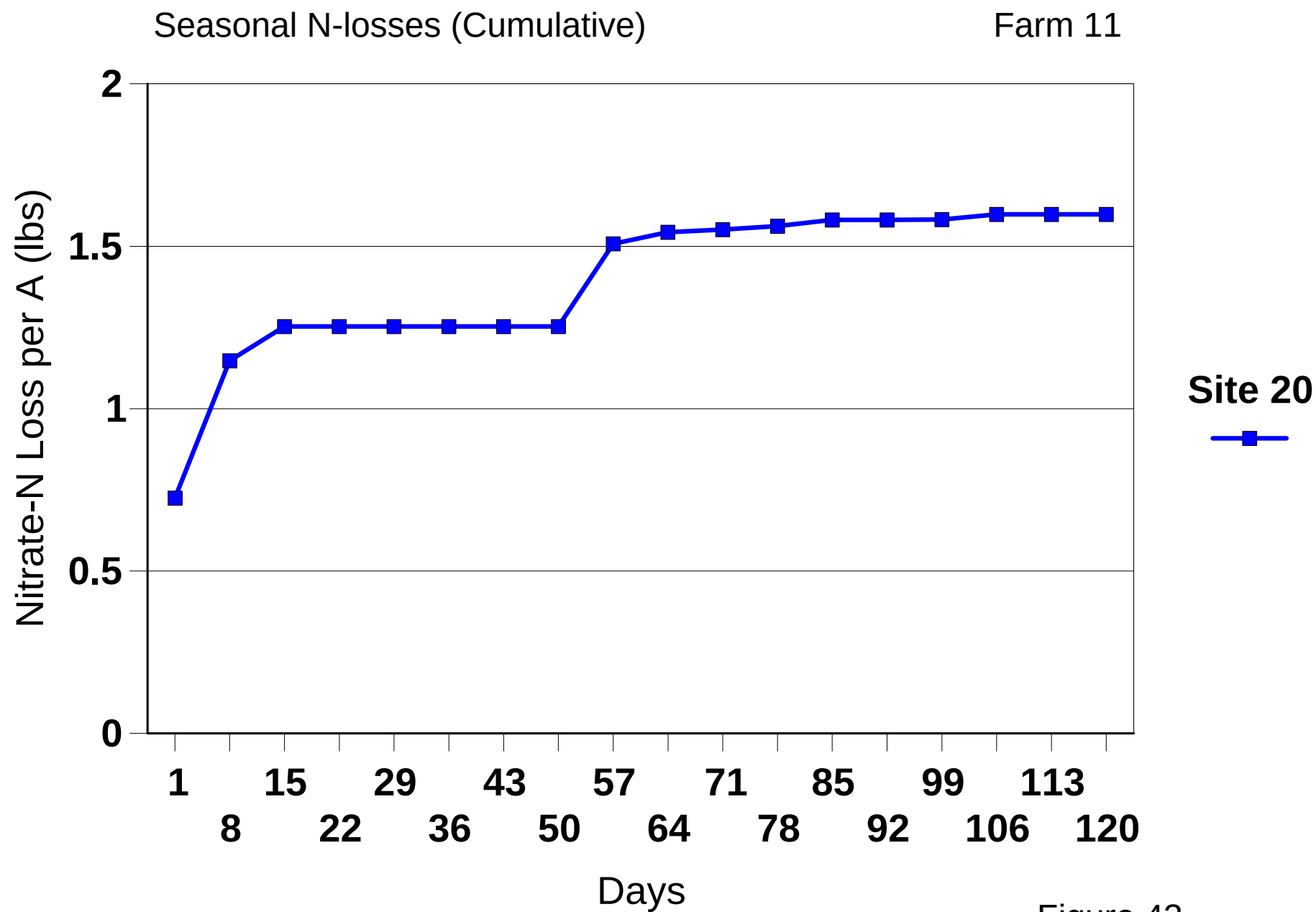


Figure 43

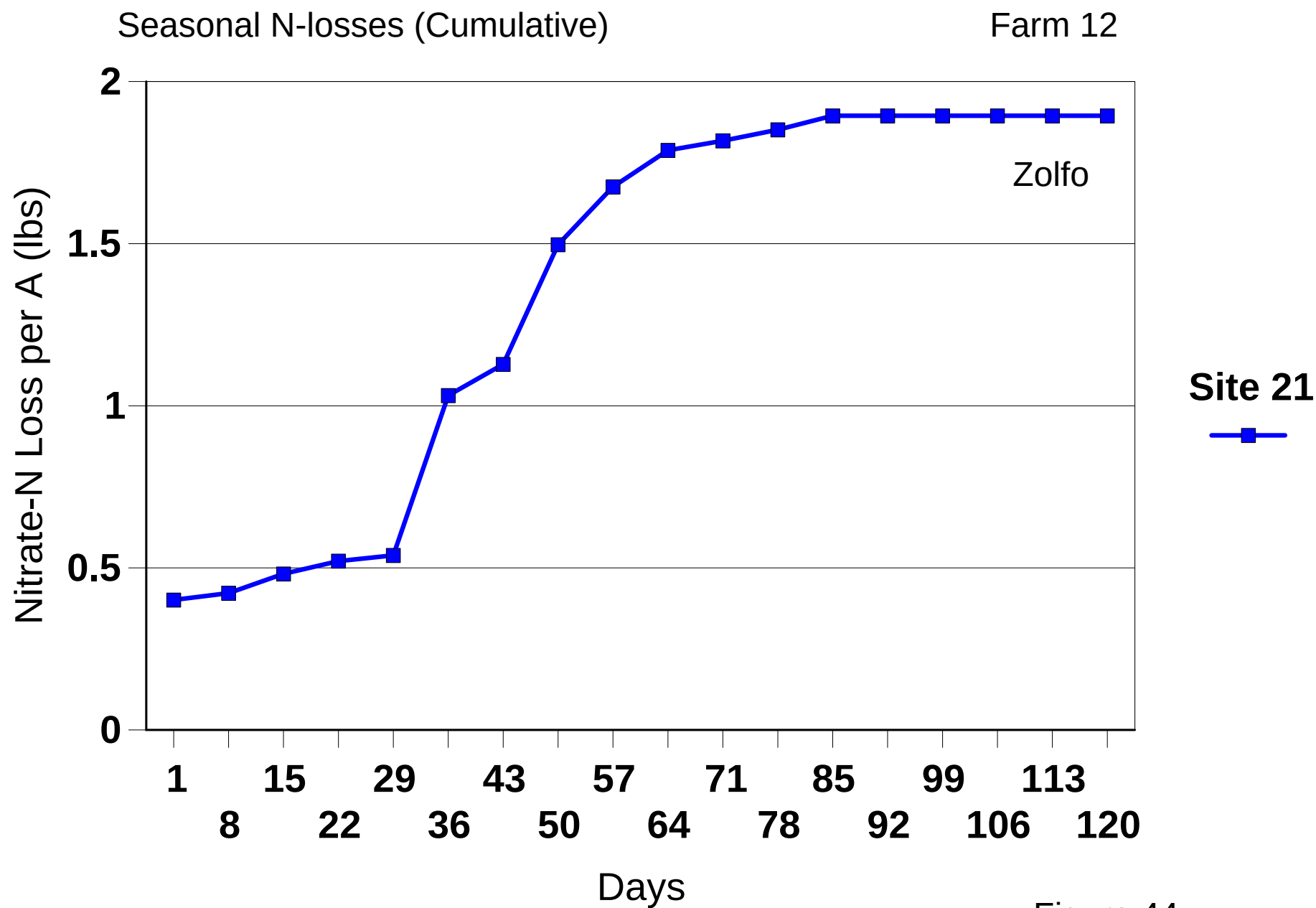


Figure 44

Seasonal N-losses (Cumulative)

## All Sites (2005-2006)

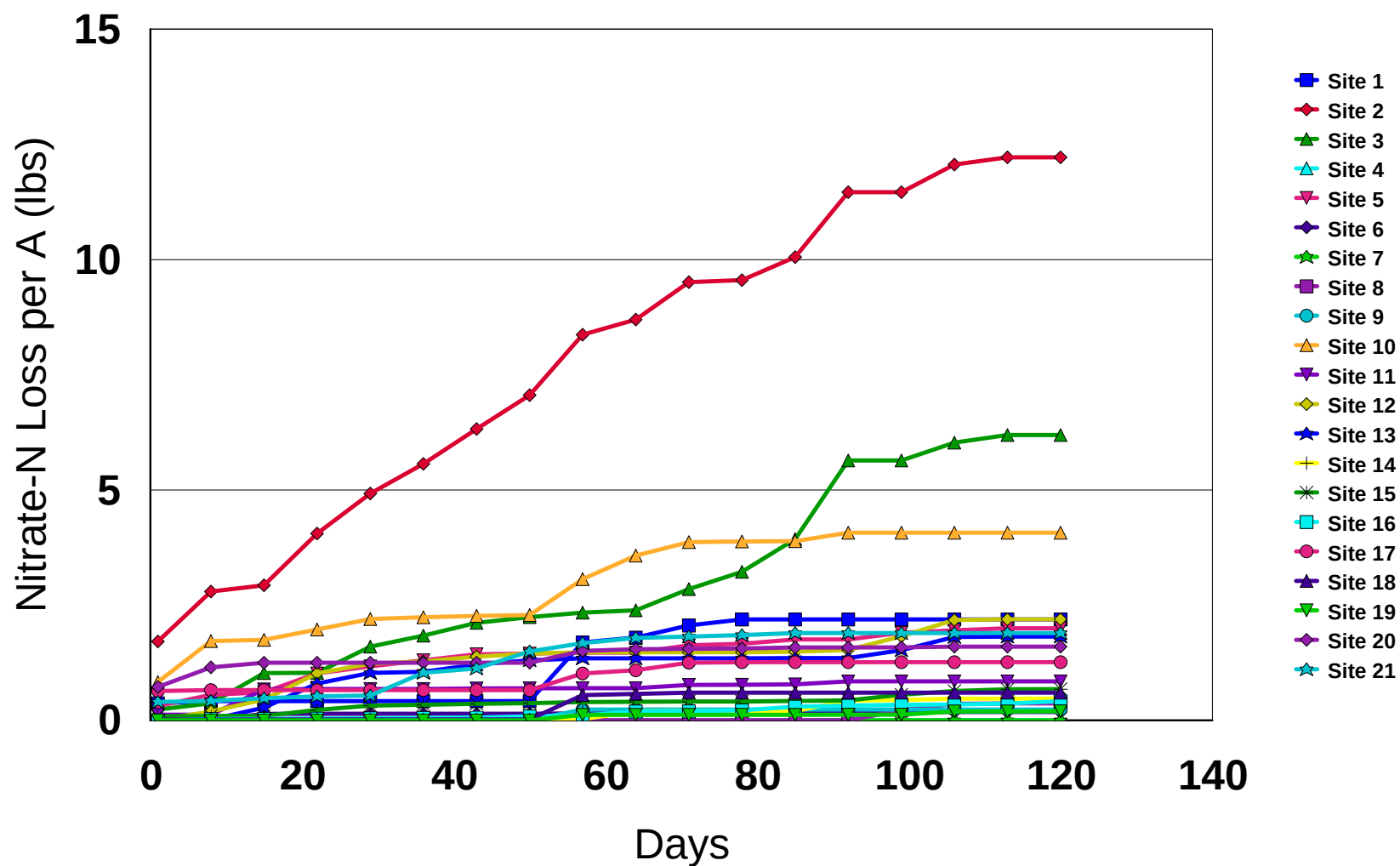


Figure 45

Seasonal N-losses (Cumulative)

## All Sites (2004-2005)

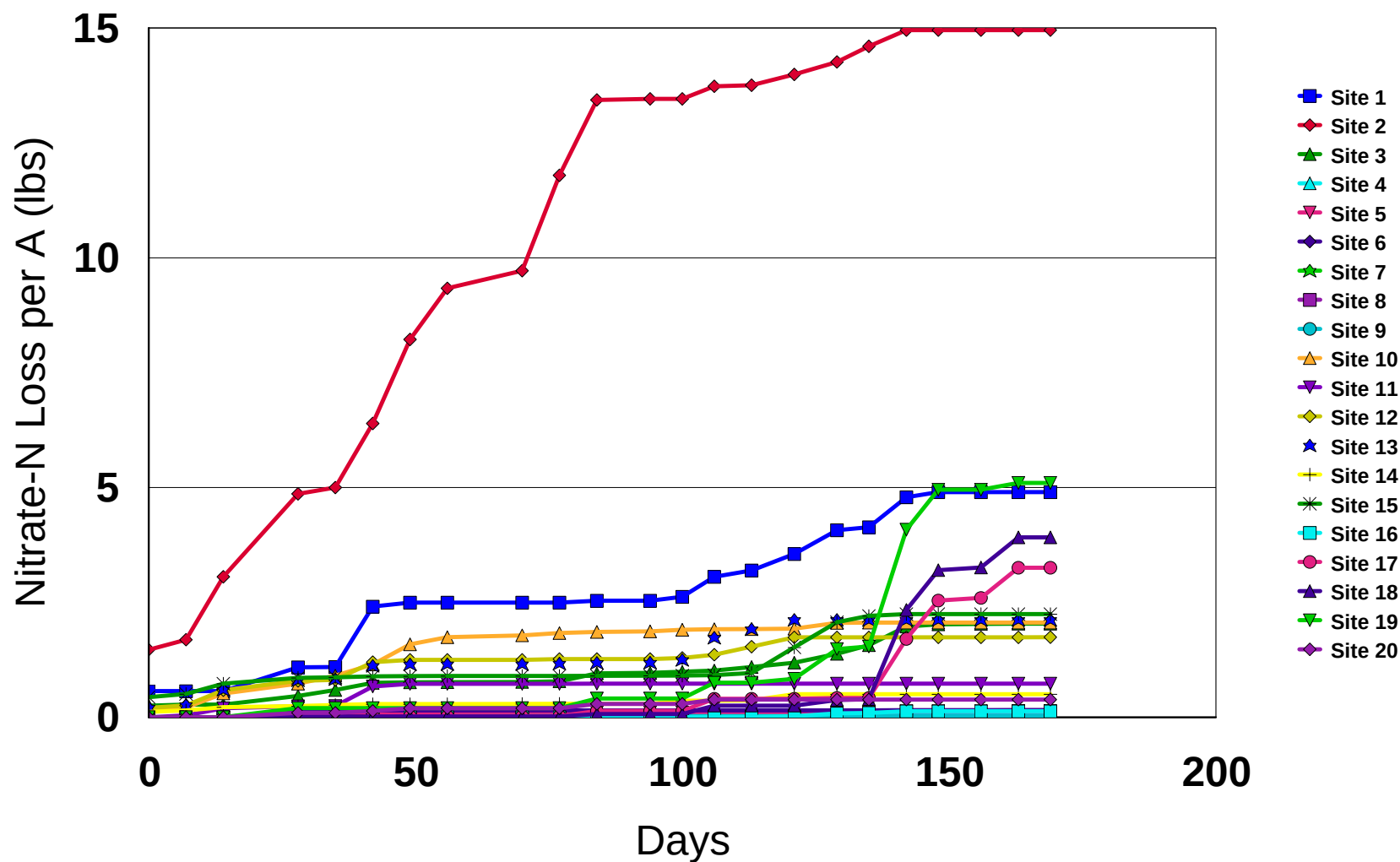


Figure 46

## 2006-2007 Progress Report

This is the annual progress report for Year 3 of the project. Overall, all the objectives that were planned were met for the third year of this study. It was initiated in August 2006, by re-identifying existing grower/cooperators who:

- 1) had production fields containing specific soil types
- 2) were willing to share specific cultural management information
- 3) would allow water quality samples to be collected from production fields on a weekly basis.

The sampling locations were the same as previous seasons (Figures 1-12).

A weekly water sampling scheme for strawberry production was implemented in November 2006 and continued through March 2007. Once strawberry production ceased, sampling continued at those locations where a double crop (i.e. melons, peppers, etc) was planted to follow the strawberries through May. A grower survey to ascertain the production inputs and management practices of the grower cooperators was implemented. The results of the survey showed some variability in management practices, but nothing extremely divergent among sites. Generally, for a projected 120-day strawberry crop, producers were applying 0 to 30 lbs N as dry pre-plant fertilizer and 0.75-1.5 lbs N applied as liquid fertilizer per day. Irrigation applications ranged from 45 min/day to 3 hr/day depending on emitter flow rate and grower preference. However the majority of producers were applying irrigation water at 60 min/day. Fertilizer was injected at mid- to late-irrigation cycle with enough time left to flush the system before the irrigation cycle concluded. Specifically, the following general conclusions resulted from the responses to the survey:

- 1) growers use drip irrigation with overhead sprinklers for transplant establishment and cold protection
- 2) crops are planted mid to late October
- 3) growers use at least five different microirrigation tube types amongst the responses
- 4) growers use drip tube with 0.24 to 0.50 gpm/100 ft application rates
- 5) growers apply irrigation rates from 0.12 to 0.26 inches/A/day
- 6) ~ 50% of growers apply no dry pre-plant fertilizer
- 7) growers that do apply dry pre-plant fertilizer apply ~ 20 to 40 lb N per acre
- 8) growers apply ~ 1 lb N per acre per day liquid fertilizer
- 9) growers use experience to decide when and how much to irrigate (with a limited number using soil moisture measurements)
- 10) growers fertigate at the end of the cycle with ~15 to 30 flush time.

Soil types of the sites identified included Immokalee, Pomello, St. Johns, Seffner, Zolfo, Kesson, Ona, Taveres, Malabar, Lake, Gainesville, Candler, Fort Meade, and Myakka. All sites had dry season water table levels below 2 m, so the

sampling procedures used the passive “wick”-type leachate collector. As stated earlier, a smaller collector was developed and evaluated. These collectors allowed for collection of water and nutrients leaching below the crop rooting zone and allowed an estimated of mass balance losses of N and water from the fields.

The results for the seasonal monitoring are shown in Figures 47 through 63. Remarkably, the results are very similar to the results from the previous 2 years for specific farms. Figure 47 shows the nitrate-N leached at any particular site for each sampling date. The results show that for the vast majority of sites, less than one lb/week was being leached with very few exceptions. Figures 48-50 show the weekly losses for each sampling site at each farm. These figures support the minimal weekly leaching that was occurring at all grower/cooperator locations.

Seasonal cumulative nitrate-N losses for each site (with soil identified) at each farm are shown in Figures 51 through 62 (scales for each figure may differ). The figures show that for seasonal accumulated leaching losses of nitrate-N, only Farm 1 had losses exceeding 5 lbs/A and most were 2 lbs/A or less. Assuming a total seasonal application of 150 lbs/A, less than 10% losses occurred. Figure 63 summarizes the seasonal cumulative results for all sites. When compared to Figures 64 and 65 (2004-2005 and 2005-2006 cumulative results, respectively) it is remarkably evident that consistent and effective water and nutrient management practices are being used by the participants in the study and they seem to be doing an exceptional job of minimizing water and nutrient losses during the production season.

These results are so consistent with the 2004-2005 and 2005-2006 results that very few modifications to existing practices are warranted. Although the results reflect the practices of the project participants only, this information is extremely valuable to the industry as a whole and provides evidence that grower participation in the state’s BMP implementation program should be encouraged and will involve very few modifications to existing practices.

# All Sites

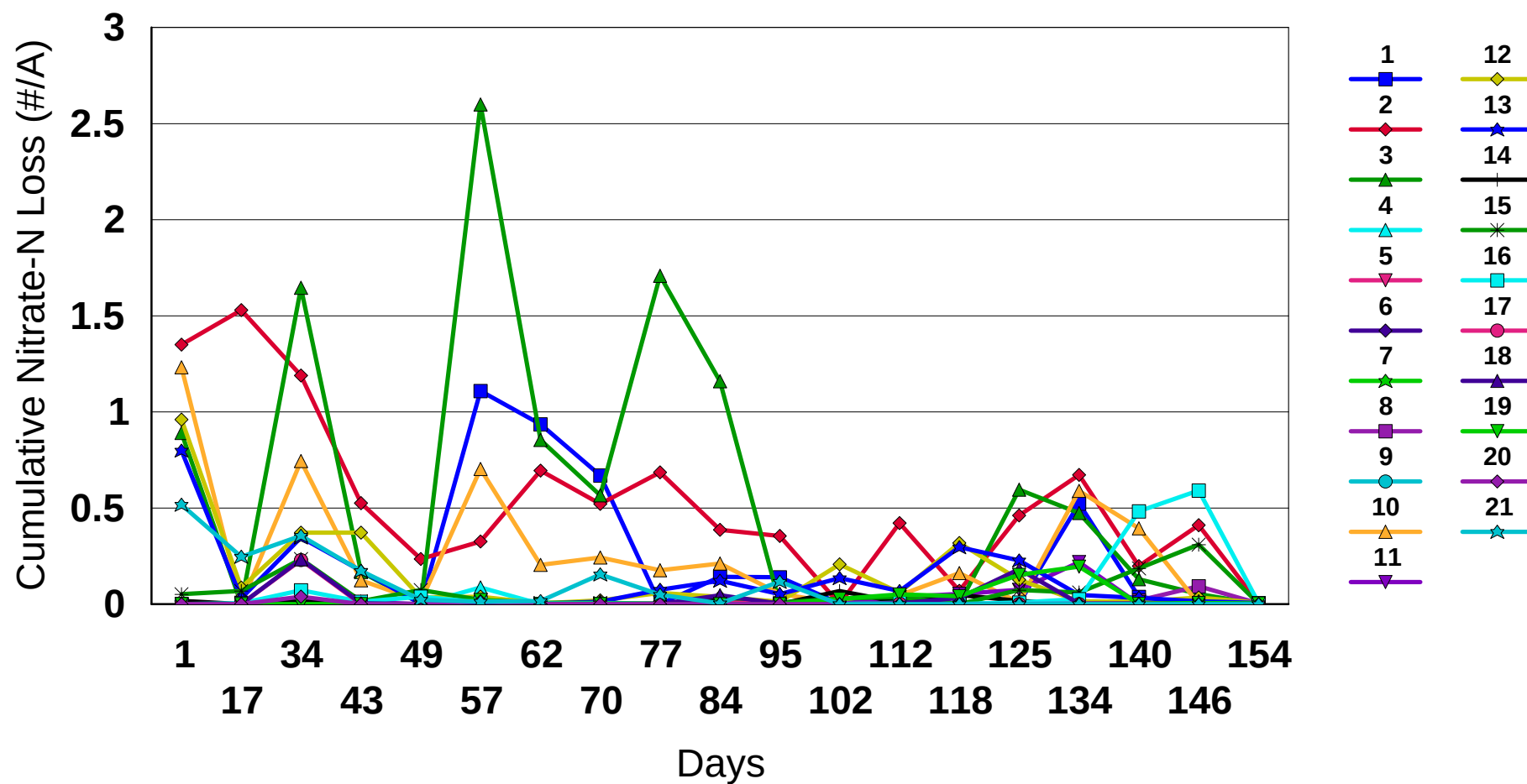


Figure 47

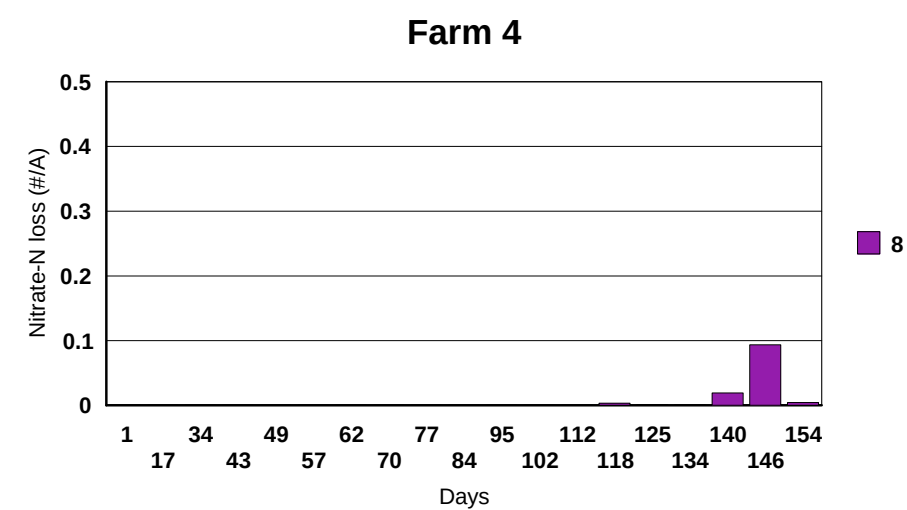
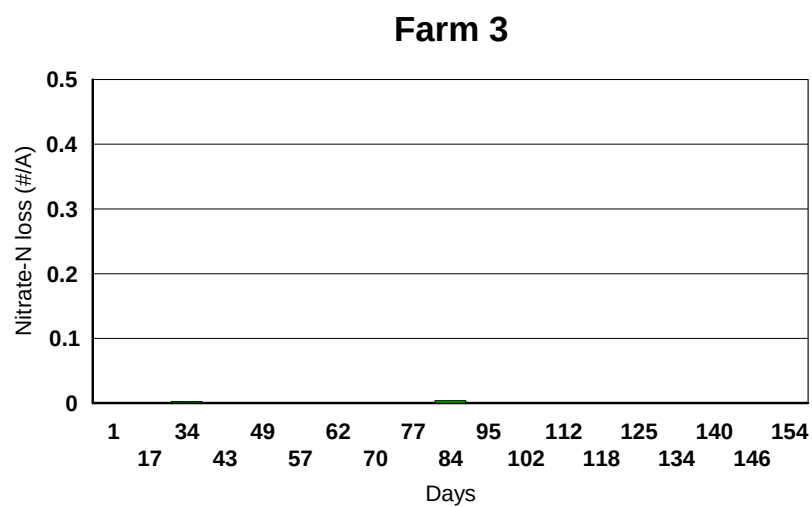
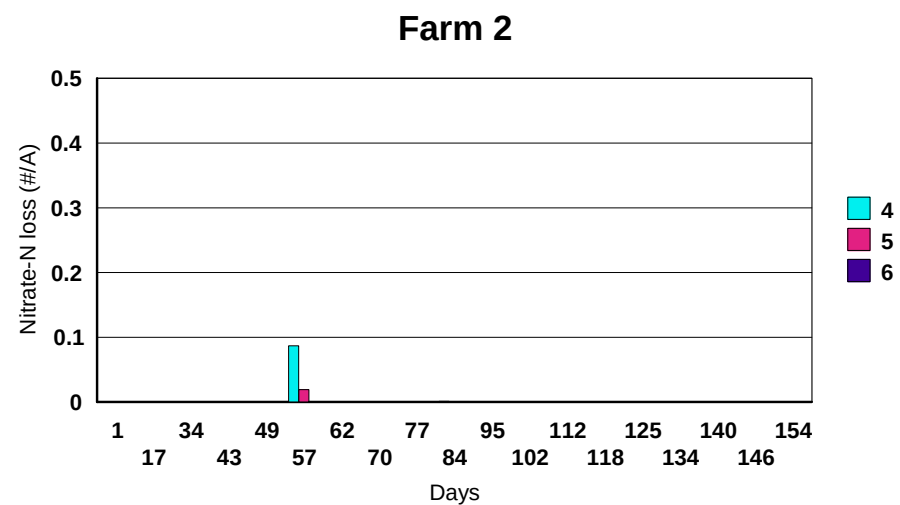
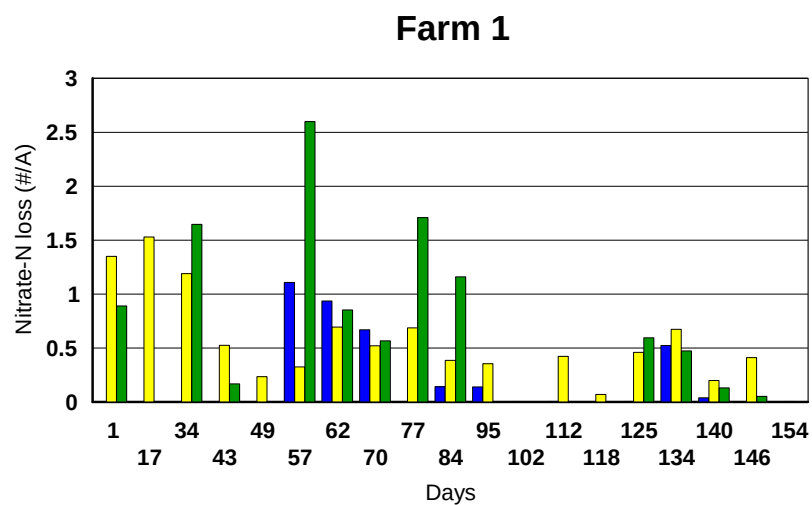
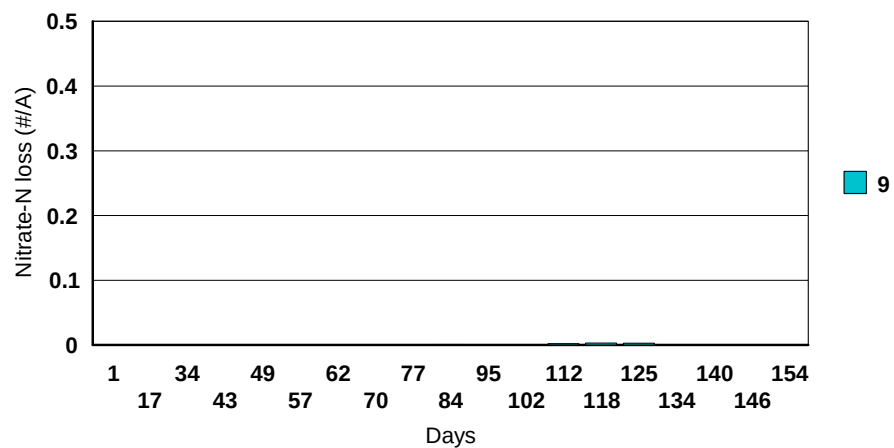
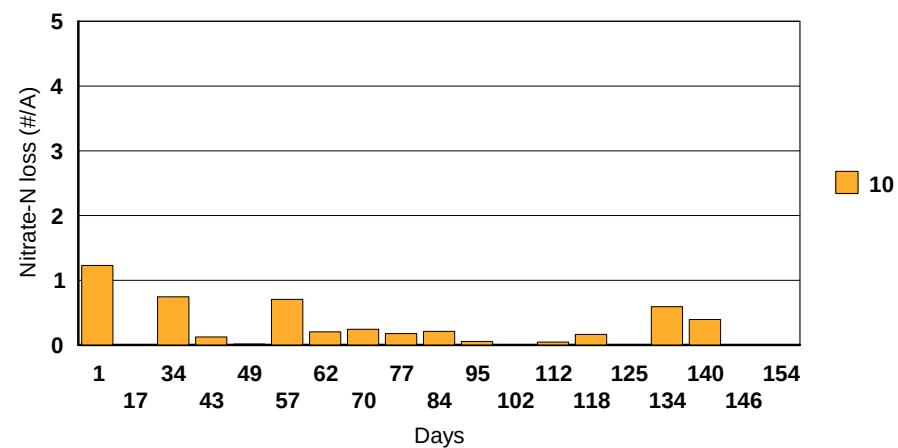


Figure 48

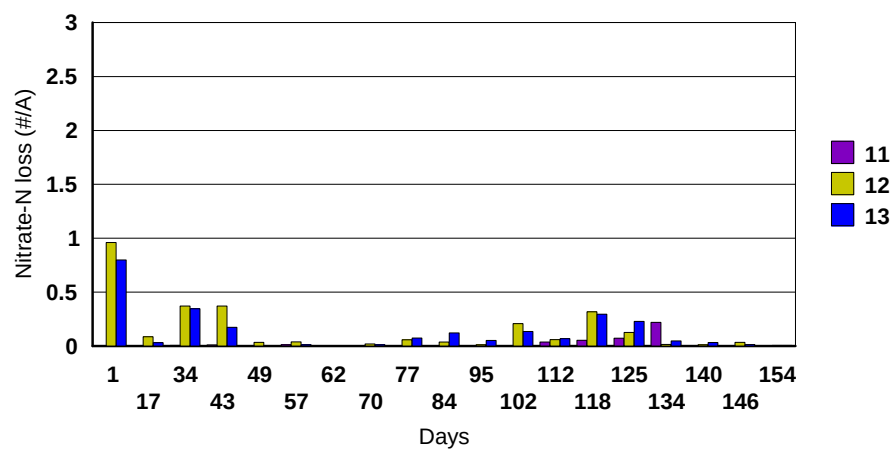
Farm 5



Farm 6



Farm 7



Farm 8

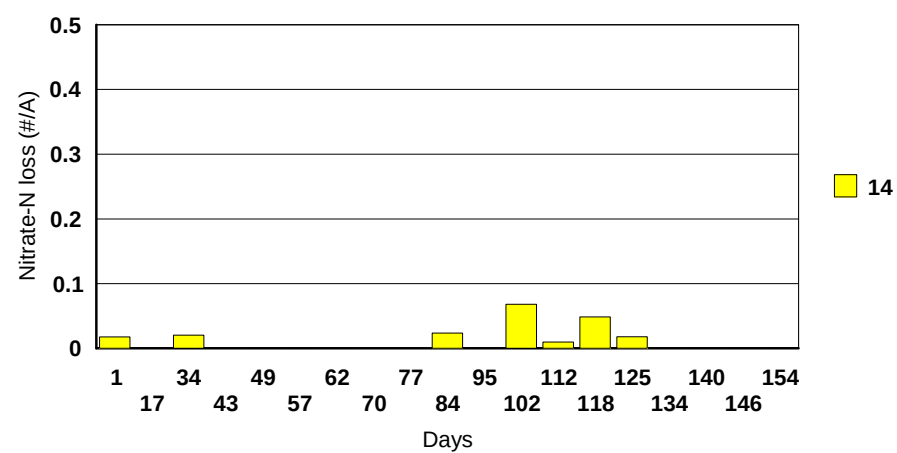
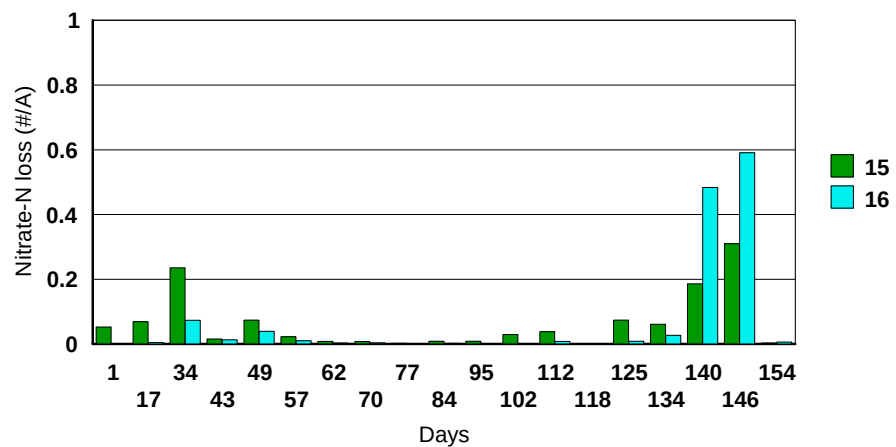
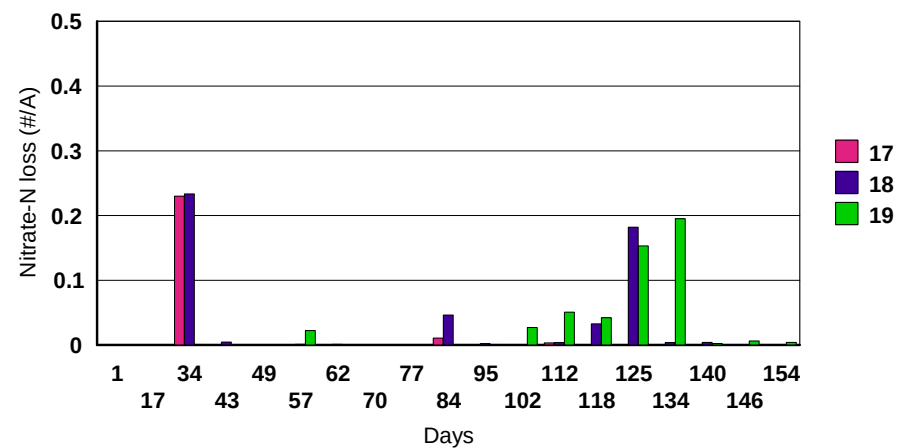


Figure 49

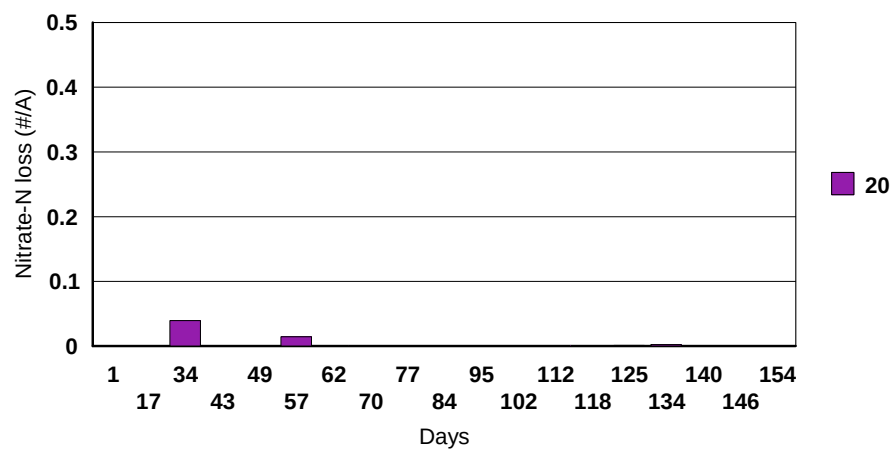
Farm 9



Farm 10



Farm 11



Farm 12

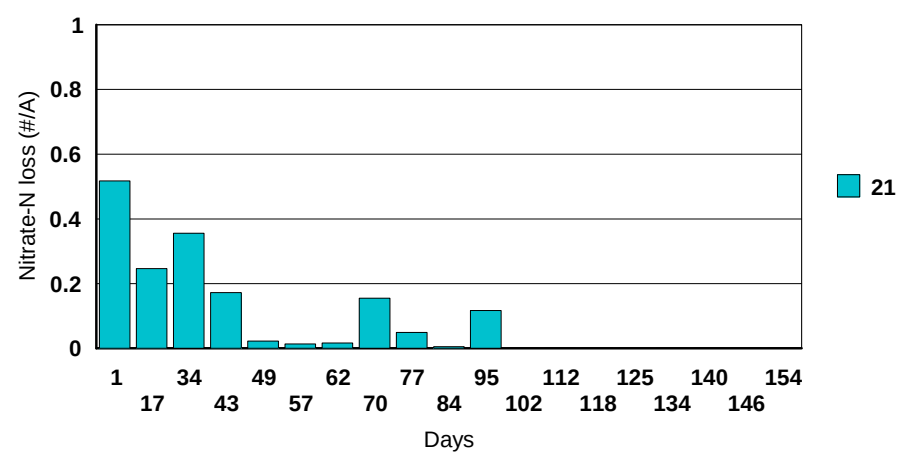


Figure 50

# Farm 1

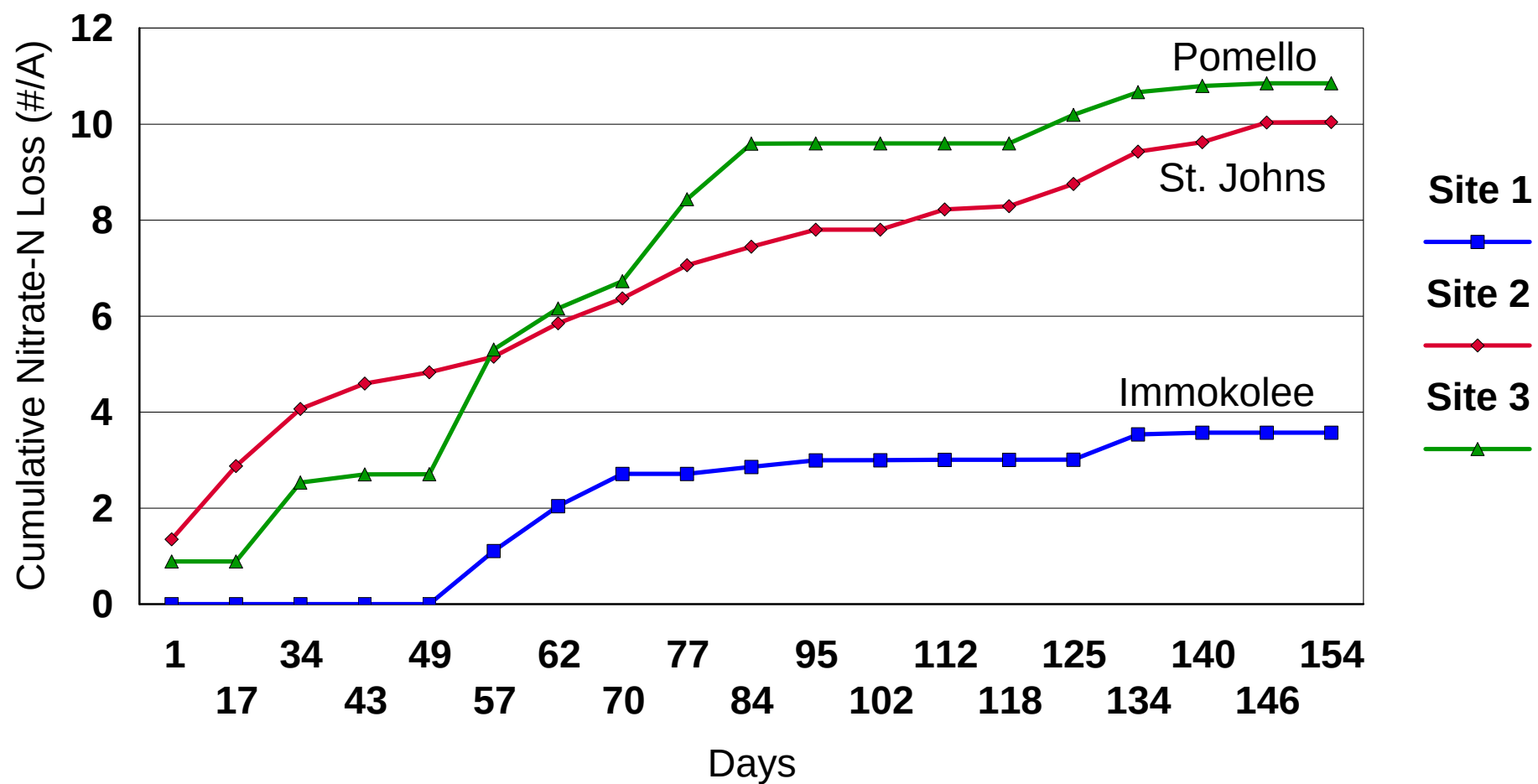


Figure 51

## Farm 2

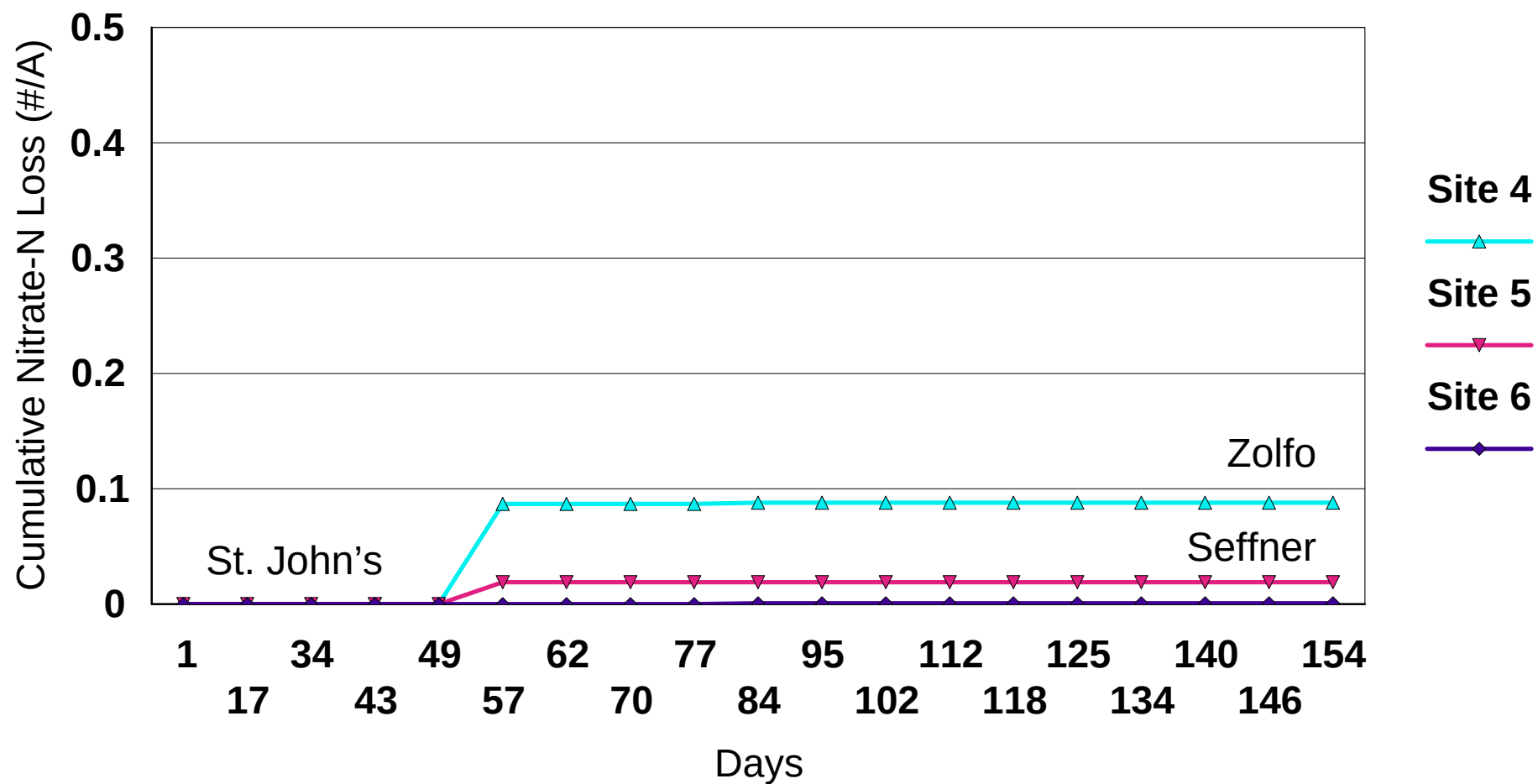


Figure 52

## Farm 3

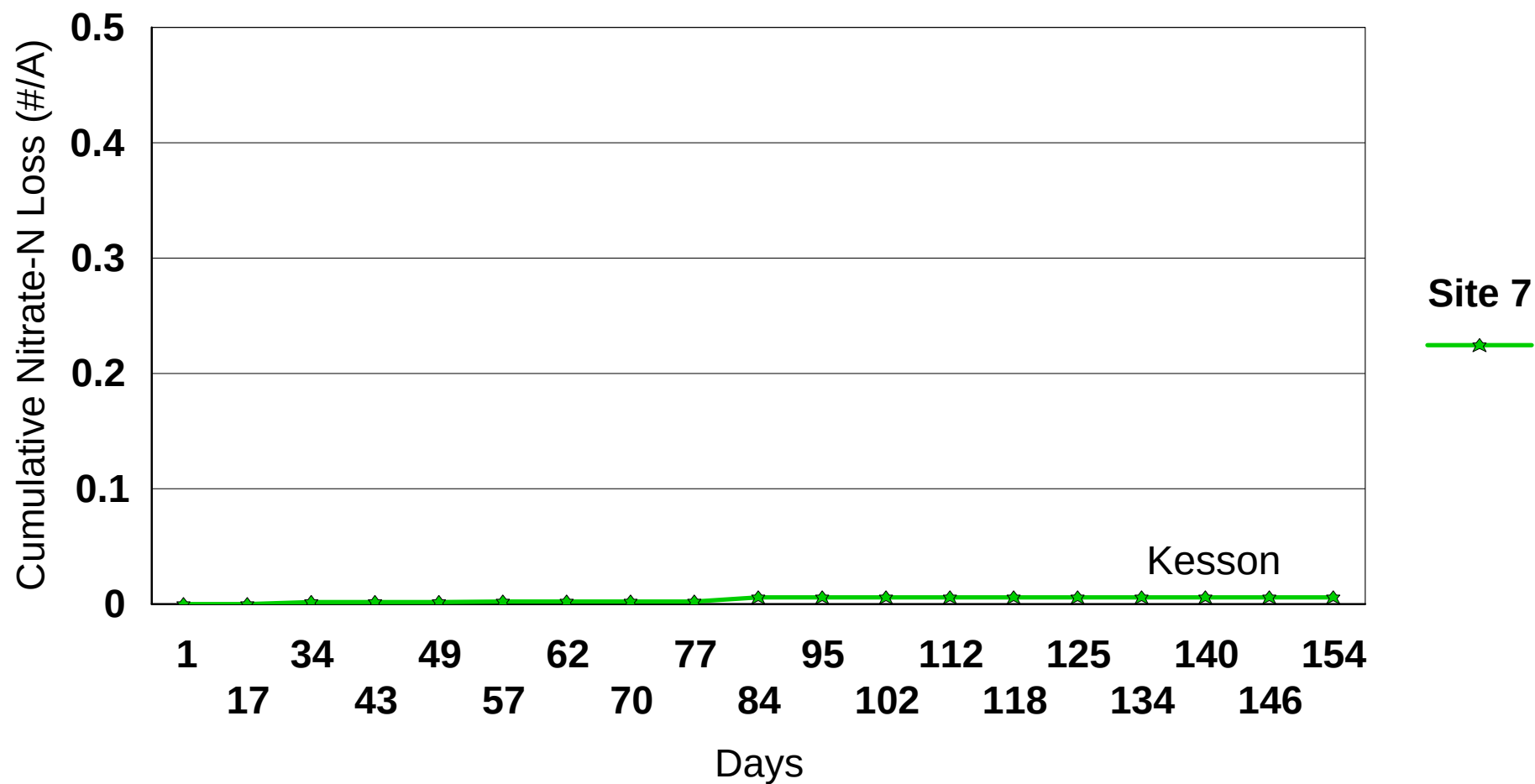


Figure 53

## Farm 4

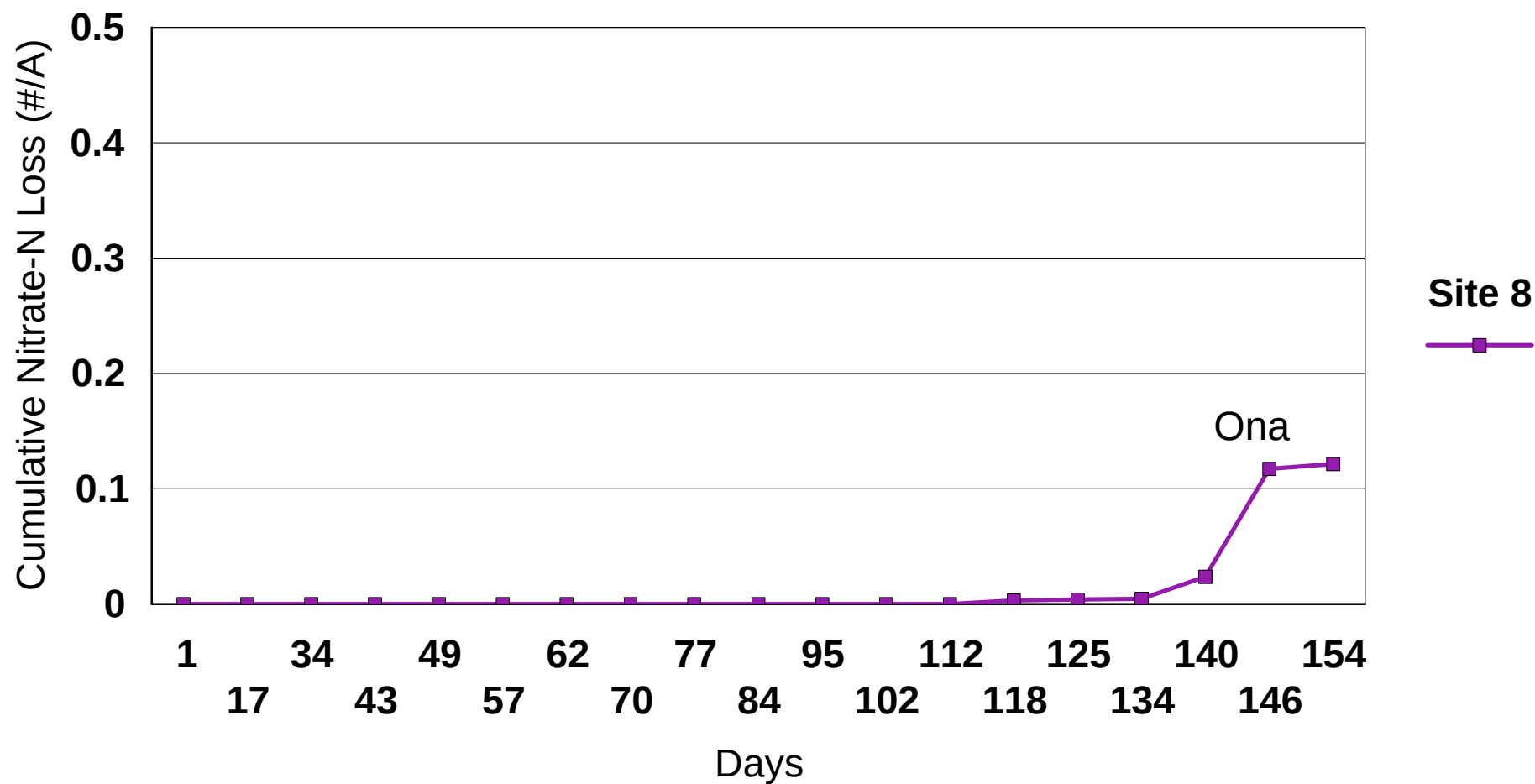


Figure 54

## Farm 5

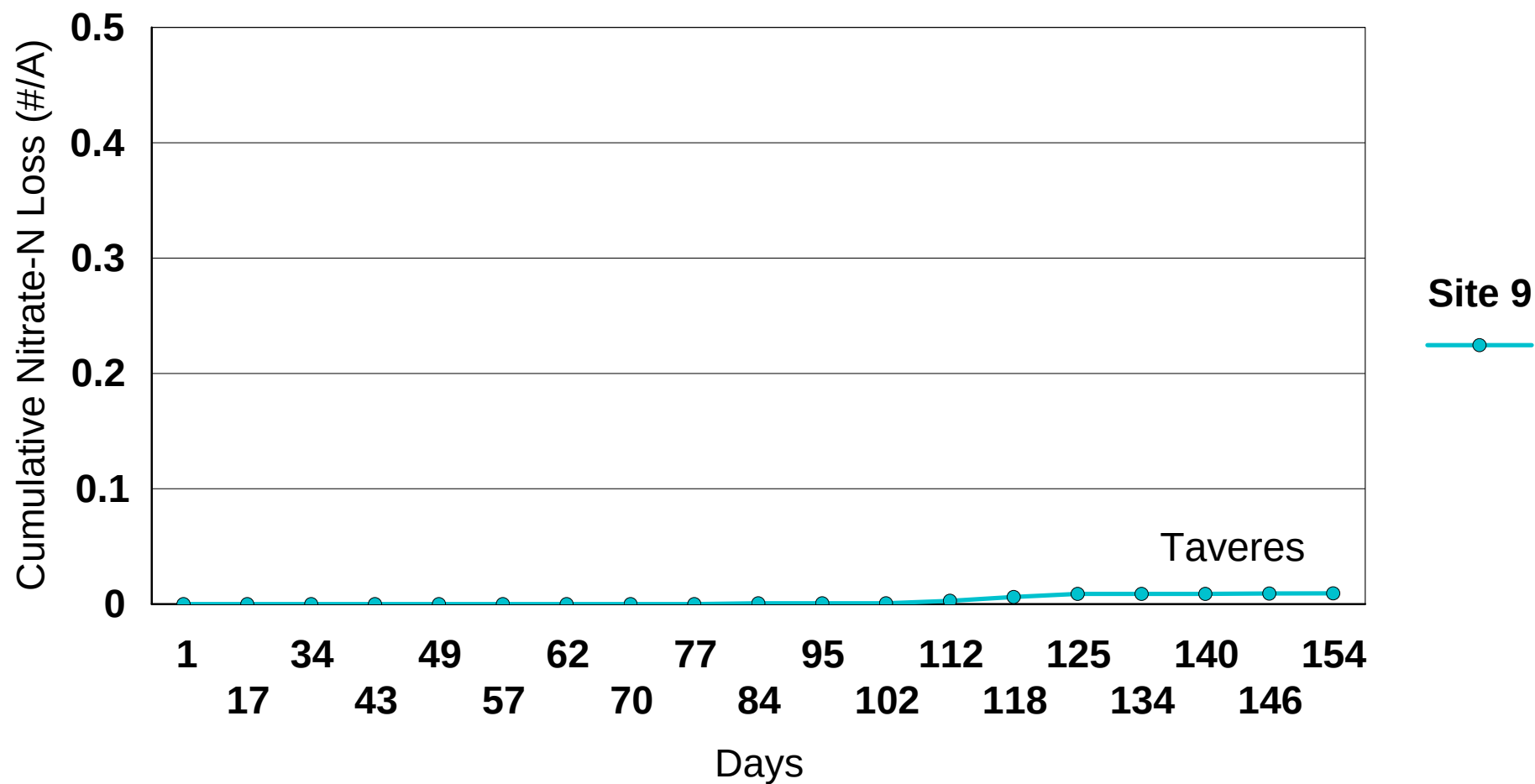


Figure 55

## Farm 6

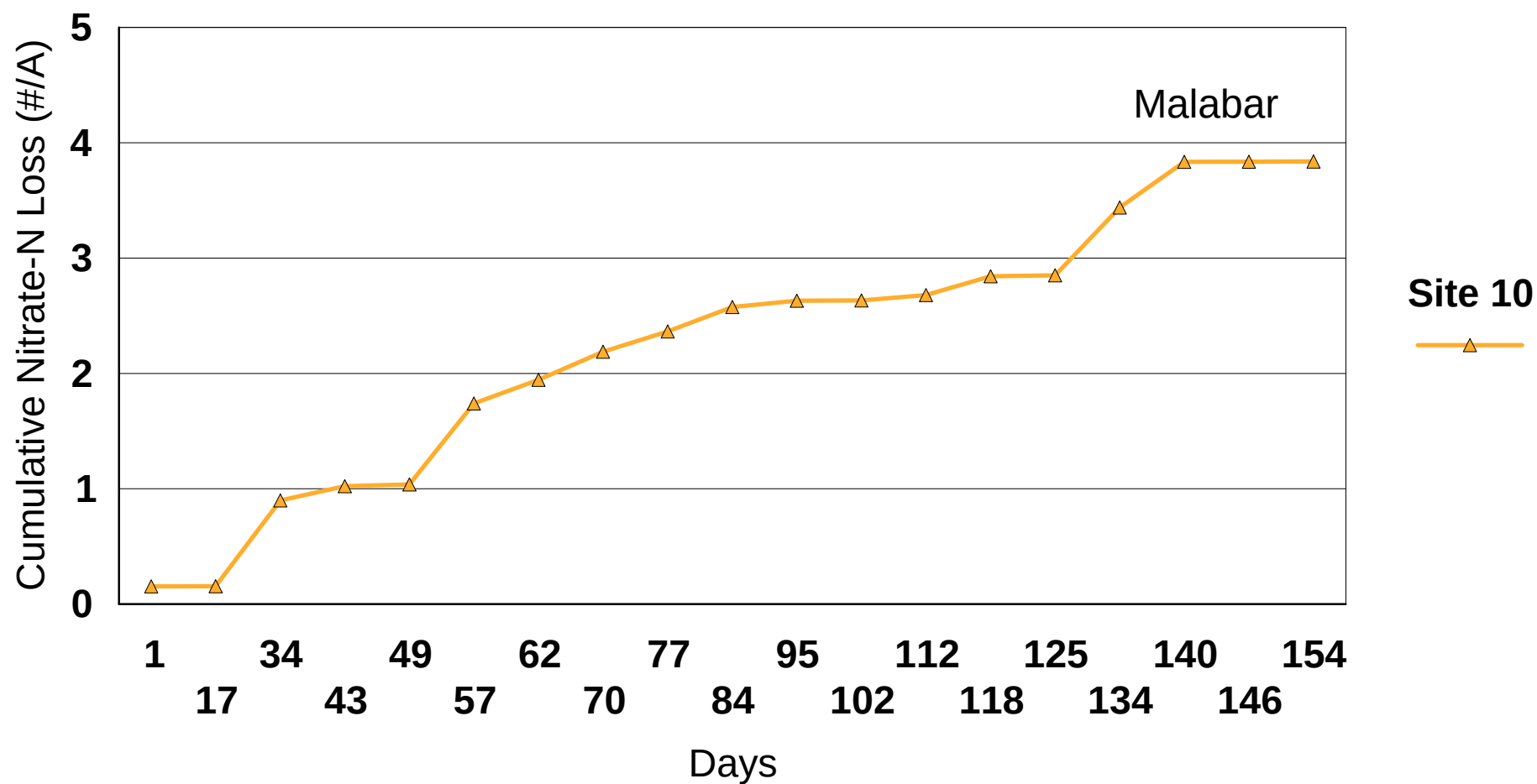


Figure 56

## Farm 7

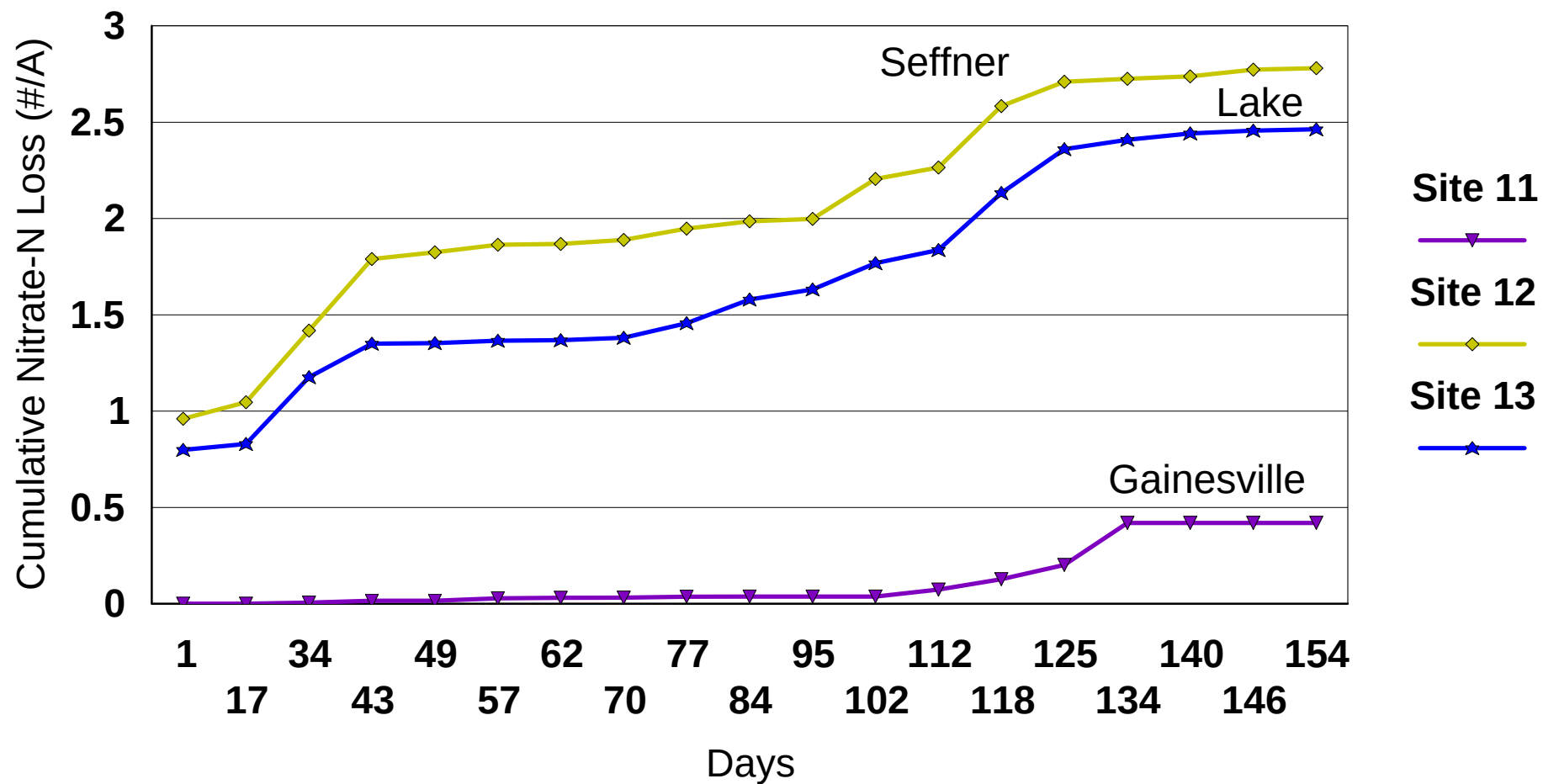


Figure 57

## Farm 8

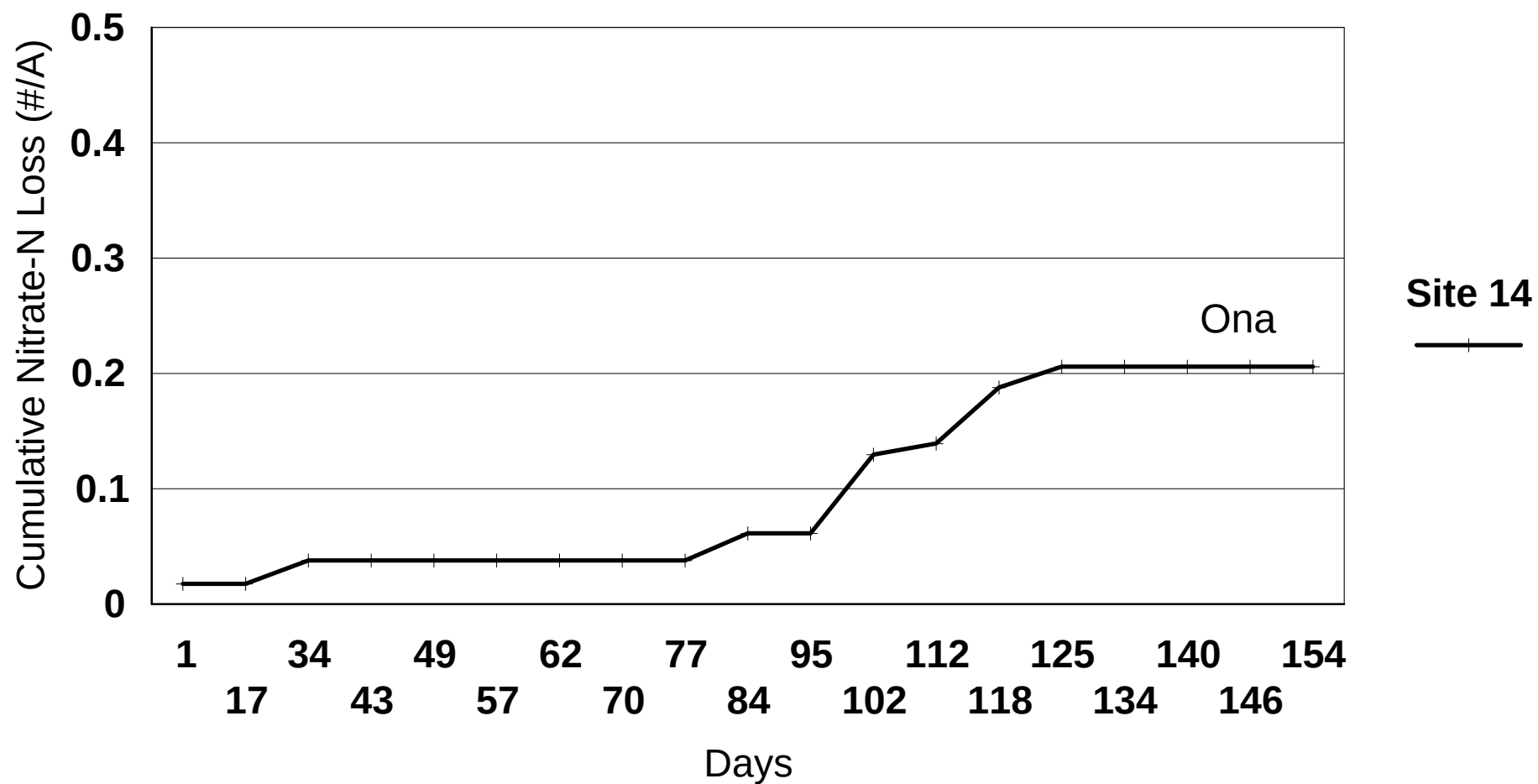


Figure 58

## Farm 9

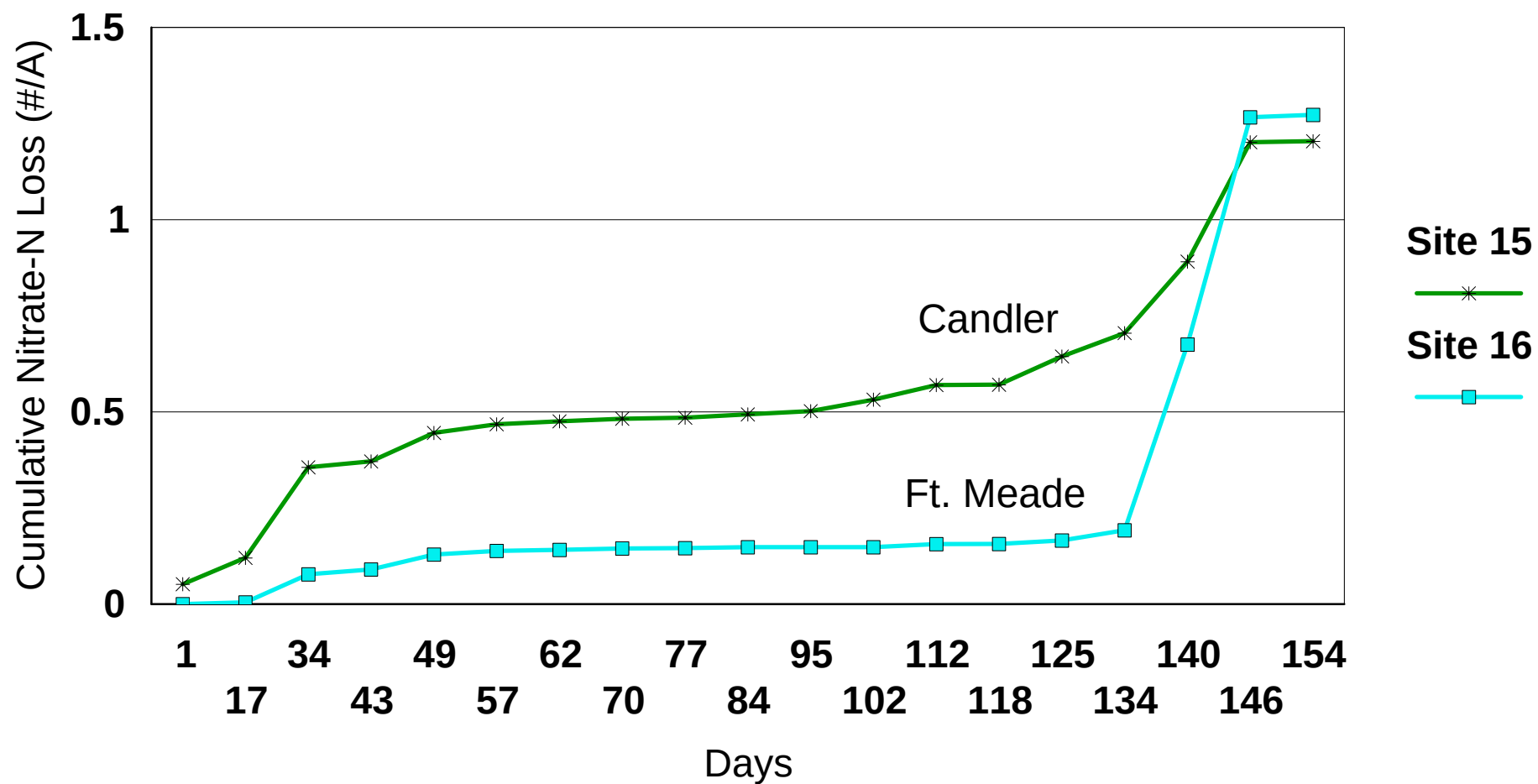


Figure 59

## Farm 10

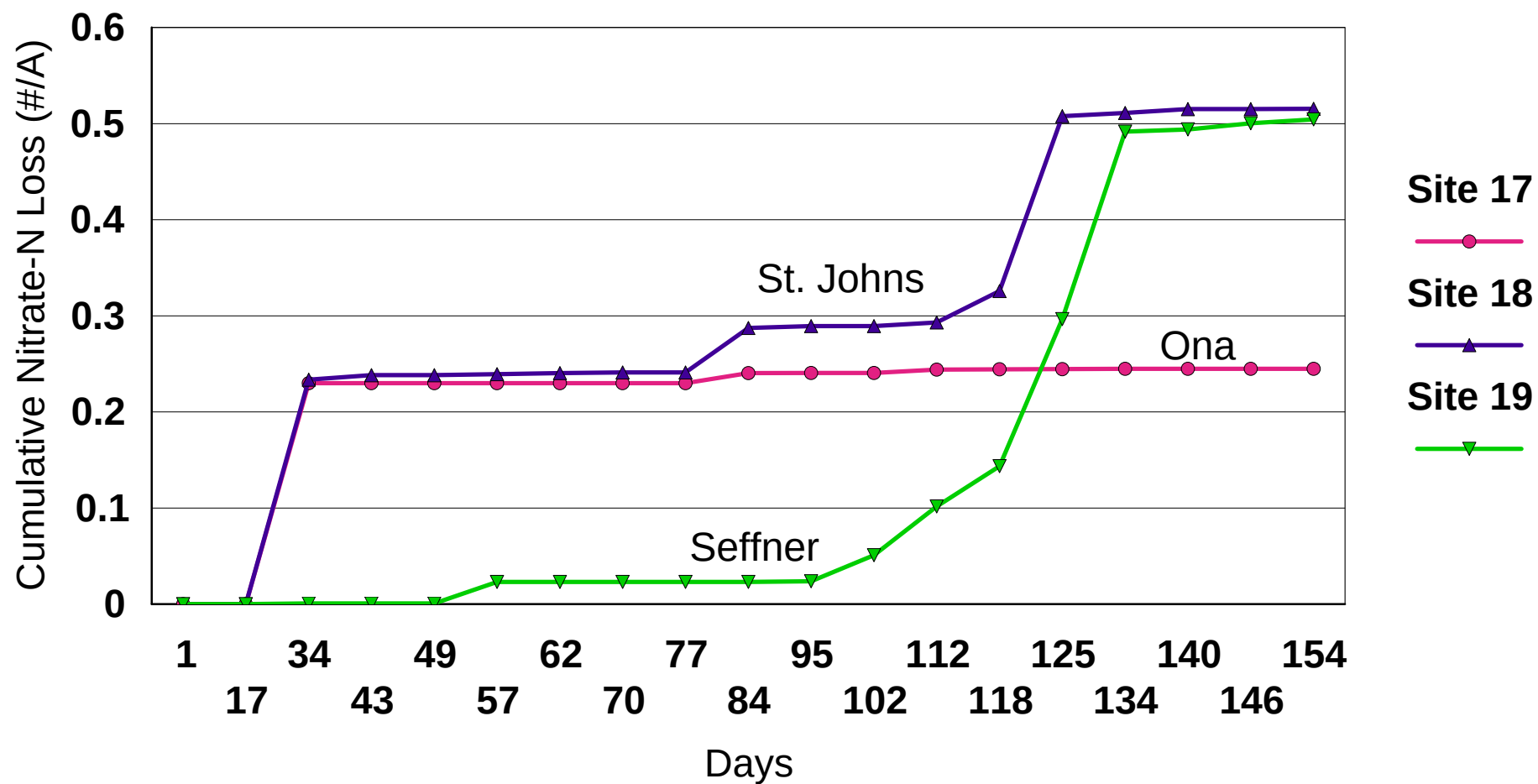


Figure 60

# Farm 11

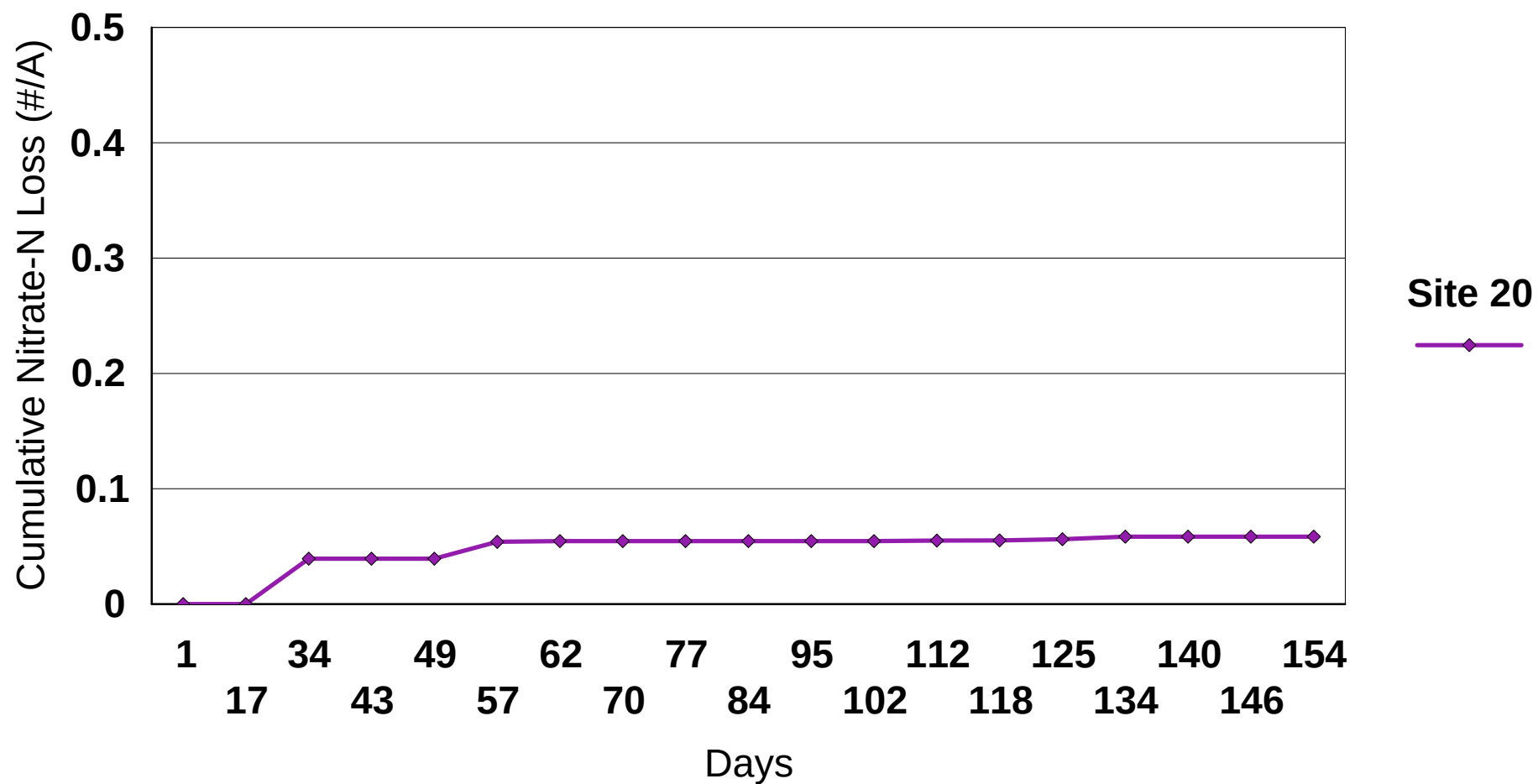


Figure 61

## Farm 12

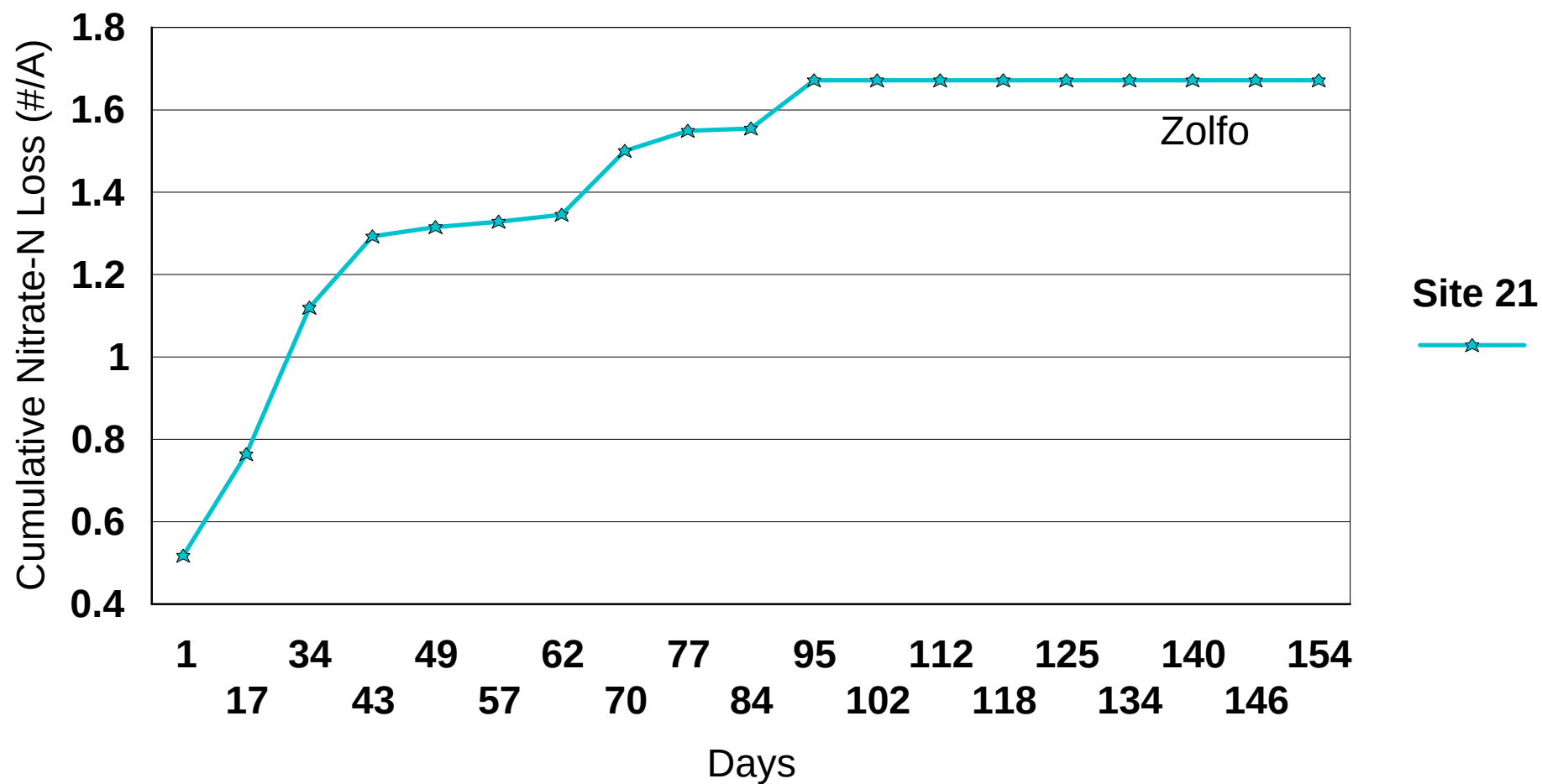


Figure 62

## All Sites (2006-2007)

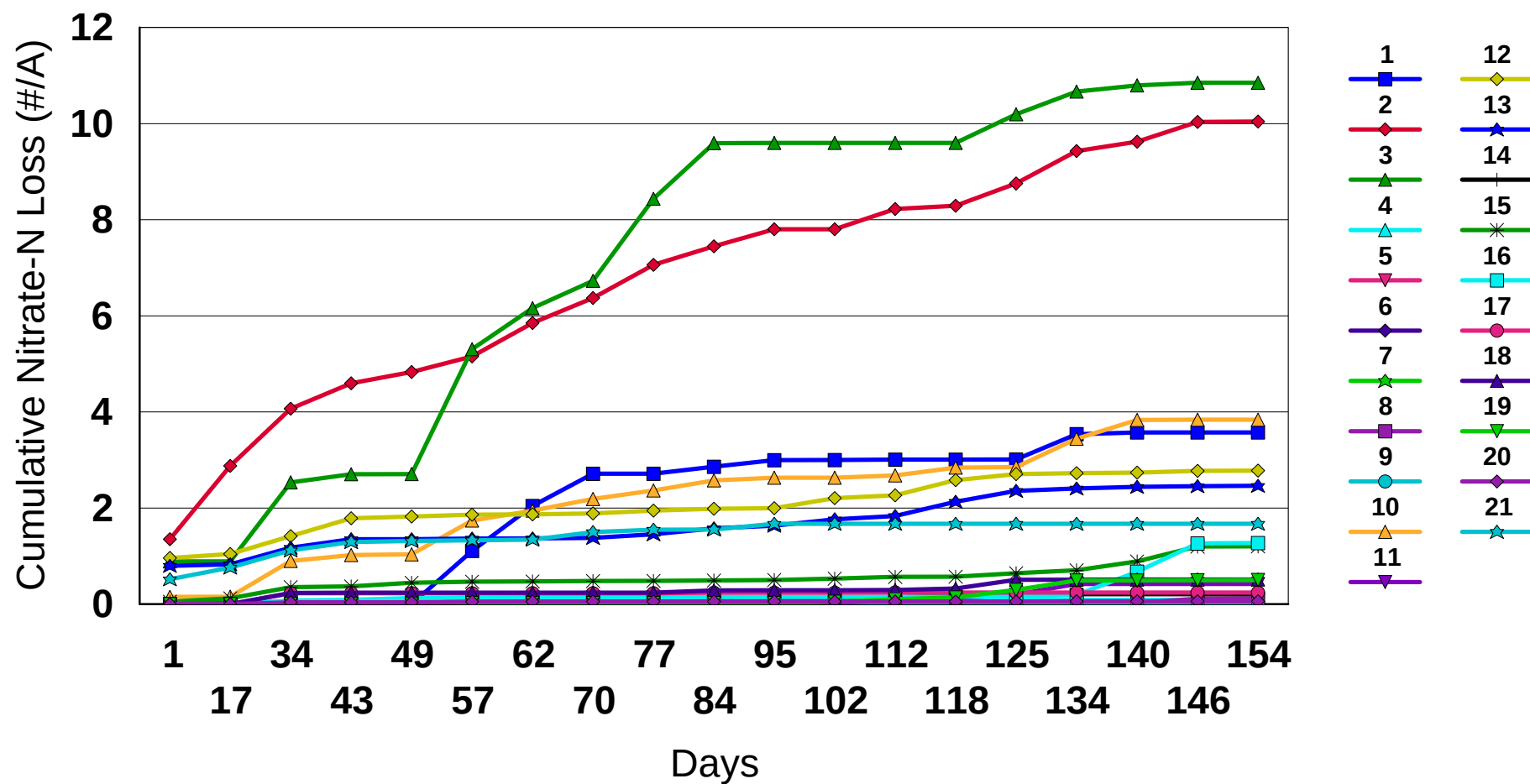


Figure 63

## All Sites (2004-2005)

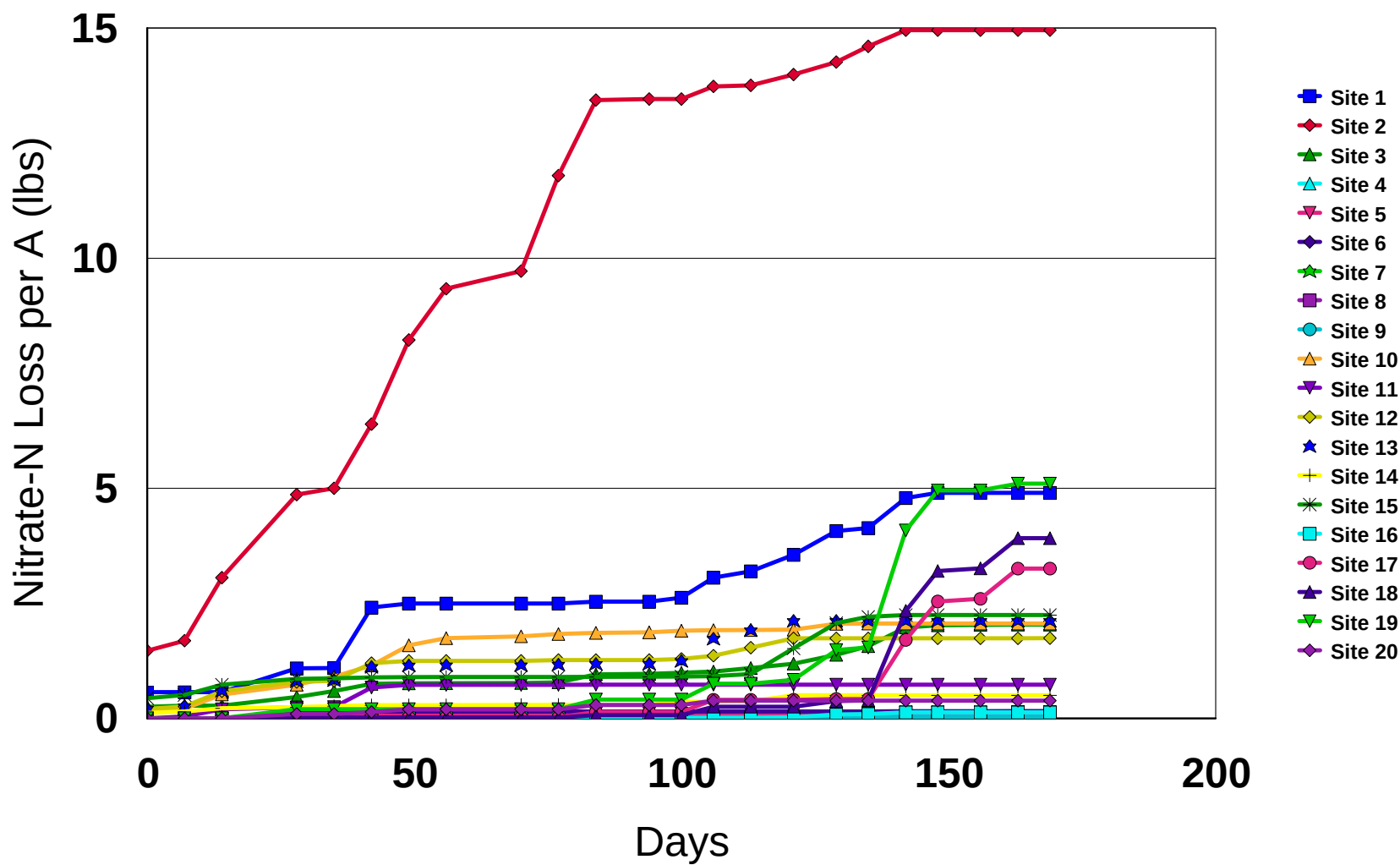


Figure 64

## All Sites (2005-2006)

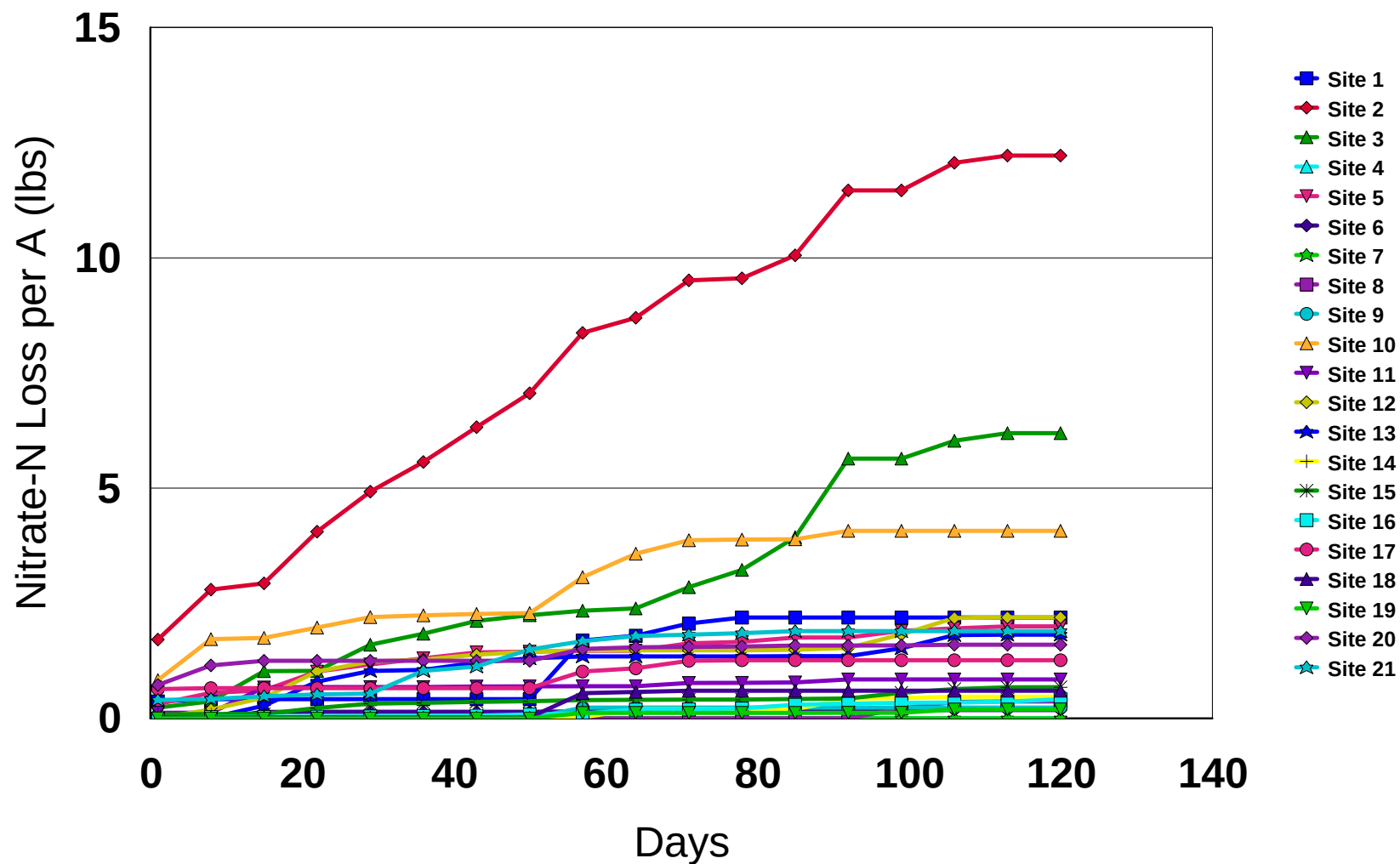


Figure 65

**Discussion - All seasons combined**

Overall, there was little seasonal variability of nitrate-N leached from each site at each farm. Individual farm irrigation and nutrient management likely influenced the overall leached N compared to other farms, but soil type may have influence leaching for those farms where similar management intensity occurred regardless of soil type. For example, Farms 1 and 7 had 3 soil types each and there were fairly consistent leaching differences among soil types on each farm over the three seasons. While these differences existed, the magnitude of these differences probably doesn't warrant large scale management changes due to soil type.

Figure 66 shows the average seasonal cumulative leaching for each year (all sites on all farms). Differences among seasons were always less than 0.5 lbs of N at any time indicating the repeatability of the results from year to year.

When one considers the considerable variability that can be experienced when conducting such a study on commercial production fields, the results from this study are remarkable. However, when one considers the BMP's that strawberry producers are currently implementing, the results should not be surprising. All of the growers in this study (and up to 95% of the industry) use microirrigation as the means of providing water and nutrient to their crop. Because strawberries are very prone to salt damage, producers accepted microirrigation many years ago primarily because of its ability to provide liquid fertilizer when and where it is needed. The water conservation advantages of microirrigation were secondary. Because accumulated fertilizer salts are to be avoided, producers are careful not too over-apply N, and because irrigation management goes hand-in-hand with nutrient management, care is taken to not to leach the applied nutrients below the root zone.

The survey of cooperators showed that 50% of the sites received no pre-plant dry N fertilizer and where it was applied, only an average of 31 lbs N was used. This lack of pre-plant dry fertilizer also shows the reliance on microirrigation applied fertilizer and the care necessary to do it right.

In conclusion, it appears that for the cooperators participating in this study, current strawberry production practices are adequate for managing nitrate-N losses from production fields. It would be assumed that the conclusion could be drawn for other growers using similar management practices.

## Average Nitrate-N Loss By Season By Season(all sites and farms combined)

