# DRAFT

FINAL REPORT

# ALASKA SOIL AND PEONY PLANT NUTRIENT STUDY – PHASE 2

2011 ALASKA GROWN SPECIALTY CROP COMPETITIVE GRANT PROGRAM

SUBMITTED TO

ALASKA DEPARTMENT OF NATURAL RESOURCES

DIVISION OF AGRICULTURE

SUBMITTED BY

**ALASKA PEONY GROWERS ASSOCIATION, INC.**

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**Appendices**

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## ABBREVIATIONS & ACRONYMS

| | |
|---|---|
| % | percent |
| ~ | approximately |
| Al | aluminum |
| B | boron |
| Ca | calcium |
| Cu | copper |
| Fe | iron |
| K | potassium |
| Mg | magnesium |
| Mn | manganese |
| N | nitrogen |
| P | phosphorus |
| ppm | parts per million |
| S | sulfur |
| Zn | zinc |

## SUMMARY

A two-year study was designed and conducted to develop baseline nutrient needs for Alaska peonies. Soil and leaf samples were collected from peony farms located throughout Alaska and the sample data were compared to sample data collected from peony farms located in the lower 48 states. The data from the project were compiled with data collected in an earlier phase of work and used to evaluate best sampling methodologies, differences between upper and lower leaf nutrient concentrations, correlation between co-sampled soil and leaf samples, changes in leaf nutrient concentrations throughout a growing season, differences between healthy and poorly-performing plants, differences between three Alaska regions, and evidence for a general nutritional improvement in Alaska peonies between 2010 and 2014.

## INTRODUCTION

### Background

In 2009, many grower members of the Alaska Peony Growers Association (APGA) were experiencing poor plant vitality (stunting, necrosis of the leaf tips, thin cupped leaves with wavy edges, interveinal chlorosis) and high mortality rates in their young peony fields. Since the literature available in the public domain does not provide the sort of nutrient data APGA growers were seeking, APGA applied for and received an Alaska Grown Specialty Crop Grant to compare soil and tissue nutrient concentrations in Alaska peonies with peonies in the continental U.S. The study was not designed to be a rigorous scientific study because it relies on farmers with only a limited amount of time and training. However, APGA felt that if the results could be reproduced year after year in strong healthy peonies, the validity of the results would become increasingly reliable. The hope was that leaf analyses could provide guidelines for our growers to evaluate the presence and cause of potential nutritional problems.

The results from that study[1] suggest that while soil nutrient levels from healthy peony fields (from both Outside and Alaska farms) vary over a wide range of concentrations (often more than an order of magnitude depending on the nutrient), the nutrient content in healthy peony leaves (e.g., from the Outside Growers' plants) have much more constrained concentration ranges. The concentrations of all the major nutrients (N-P-K-Ca-Na-S) in peony leaves varied by only a factor of one or two in healthy plants, and the concentrations of the trace elements (Fe-Al-Mn-B-Cu-Zn) generally varied between factors of five and six. These results suggested that tissue sampling could provide a better means to assess peony nutrient deficiencies than soil sampling alone.

[1]Richards, D., 2010. *Determining a Baseline of Existing Fertility Applications in Alaskan Peony Production compared to Oregon Peony Production, final report* prepared for the Alaska Peony Growers Association, Inc. and submitted to the Alaska Department of Agriculture under the Specialty Crop Competitive Grant, December 29, 2010.

## Project Objectives

In 2011, APGA was awarded a follow-up Specialty Crop Competitive Grant to continue the first nutrient study. Phase 2 of the project involved collecting samples for another two growing seasons to address the following goals:

1) Confirm the Phase 1 results and identify preliminary target nutrient levels in support of our long-term goal of providing reliable target leaf nutrient levels (shortage, below normal, normal, above normal, and excess) for our growers.
2) Analyze if differences between new (upper) and basal (lower) peony leaves can assist in identifying nutrient deficiencies.
3) Identify potential soil nutrient deficiencies from co-sampled soil samples.

## Project Approach

The approach taken for the project involved the following activities:

1. Following the approach used by New Zealand peony growers to monitor nutrient levels, the project team decided that all growers would collect one soil and one leaf sample at the disbudding stage using the uppermost fully formed leaf plus one soil sample when the plants are being cut down in the fall. The fall soil sampling was designed primarily for the growers' use in identifying fertilization requirements for the following spring.
2. Outside growers would collect only one leaf sample at the disbudding stage for comparison purposes.
3. Three Alaska growers would collect soil and leaf samples every two weeks throughout the growing season using both the basal and uppermost fully formed leaves for analysis. This task would provide the comparisons between basal and upper leaves envisioned by the proposal as well as changes in nutrient levels across a growing season.

In 2012, 14 Alaska and five Outside farms signed up to collect upper leaves at the disbudding stage. However, only one of the five Outside growers and 10 of the 14 Alaska growers that had signed up to collect the disbudding-stage samples collected their samples. In addition, of the three Alaska growers assigned to collect samples every two weeks, none of them were able to collect the entire set of samples.

In the 2013 growing season, Alaska encountered a long wet spring followed by a record-setting warm June which resulted in normal spring-time activities (weeding, fertilizing, spraying, etc) being conducted over a shortened timeframe and, in many cases, alongside harvest activities. In addition, the extremely hot weather that blanketed the state during the harvest season reduced the peony bloom season from a normal 4 to 6 week period to 2 weeks. Since the grant work is largely carried out voluntarily by our grower members, sample collection is only one of many tasks that the growers needed to accomplish during the summer. However, few, if any, farms were prepared for the increased labor needed to handle the shortened

timeframe for spring maintenance and for cutting stems at harvest time. The unfortunate outcome of these weather anomalies was that the growers were not able to collect the necessary samples for our project.

Thus, the second year of sampling was postponed until 2014. Before starting the 2014 sampling program, the research committee reviewed the results from the 2012 events and identified methods to enhance the program. First of all, the sampling program was simplified to address our relatively poor completion rate (81%) in 2012. In order to improve our completion rate, the project was modified in two important ways.

- The sampling scheme was simplified by dropping the biweekly and end-of-season sampling events in order to focus on assessing the nutritional status of the peonies at their dis-budding stage.
- APGA hired UAF researcher and APGA member Dr. Mingchu Zhang to collect all of the Alaska samples, compile the 2014 data, and prepare a large portion of the data evaluation and project report. This relieved the individual growers from taking the time to collect the samples, ensured that all the samples were collected, and enabled uniform sampling protocols to be used at each farm.

One other problem with the 2012 sampling had involved deciding which peony plants to include in the composite leaf samples. The growers were not certain if they were to collect leaves from poorly performing plants or healthy plants or both. For the 2014 season, samples were collected from both poorly performing plants and reasonably healthy looking plants from each participating farm based on a visual inspection at the time of sampling. In addition to tracking samples by healthy and not-healthy, samples were tracked by variety. Sets of "good" and "poor" Sarah Bernhardt samples were collected from all but two of the 21 Alaska farms and sets of "good" and "poor" sets of Duchesse de Nemour samples were collected from 16 farms.

Twenty-three growers signed up to participate in the project, including eight from the Interior, four from south-central, nine from the Kenai Peninsula, and two from Outside. All of the Alaska samples were collected by Mingchu Zhang and Bob Van Veldhuizen between the end of June and the middle of July. Of four Outside growers who agreed to collect samples, only two submitted samples.

## Definitions

The following terms are used in this report using the definitions below.

*Bottom (basal) leaf (leaves).* Samples of peony leaves collected from the oldest leaves plus petiole at the bottom of the plant.

*Composite leaf sample.* A sample of leaves collected from 10 to 20 different plants within one variety or block, generally equal to about two cups of leaves.

*Composite soil sample.* A soil sample collected from 10 to 20 different locations within the field or block of peonies. Sampling depth was generally from three to six inches below ground level.

*Outside data (growers).* Peony data or a peony grower from the continental United States.

*Target range.* A nutrient's range of concentrations obtained from Outside peony plant leaves.

*Tissue sample.* Leaf sample.

*Upper leaf (leaves).* Samples of peony leaves collected from the first full leaf plus petiole at the top of the plant.

## Analytical Laboratory

All samples collected for this project were analyzed by Brookside Laboratory located in New Bremen, Ohio.

# DATA COMPILATION AND ANALYSIS

Appendix A contains a compilation of all the analytical data that has been obtain from the 2010, 2012, and 2014 growing seasons. Data obtained from each farm are referenced by a location identifier rather than by farm name for privacy purposes.

## Nutrient Target Ranges

The principle thesis of the APGA studies is that the nutrient content in healthy Alaska peonies should mimic the nutrient content in peonies that have grown for many years in the lower 48 states. For that reason, this project attempted to collect tissue samples from Outside peony growers each year that Alaska samples were collected. Adelman Peonies, Hollingsworth Peonies, Oregon Perennials, and A-1 Peonies have generously collected samples in our support.

Chart 1 and Table 1 summarizes the data from Outside peonies, including the upper and lower range of concentrations as well as the average concentration for each nutrient. These data are referred to as our "target ranges" and are used for comparison purposes to evaluate data from Alaska plants.

## Comparison of 2010 and 2012 Basal Leaf Sample Data

Chart 2 shows the range of 2012 data obtained from basal leaves in comparison to the range of the 2010 samples, all of which were from basal peony leaves. In general, the range for each nutrient is smaller in 2012, possibly due to the smaller number of samples collected in 2012. The average concentrations are practically identical between the two years for N-P-K and the same or higher in 2012 for the other nutrients except for copper and zinc.

## 2012 Upper Leaf Concentrations Week 0 thru Week 10

Three farms (ZUMA, PEONY, and MERLOT) collected composite upper leaf samples approximately two weeks apart starting when the peonies were at the disbudding stage ("Week 0"). Chart 3 provides bar charts for each individual analyte to illustrate the compositional changes over time in the upper leaves for the three farms.

The major elements generally had similar concentration trends across the growing season for all three farms. In general, the upper leaf data from the three farms show:

- *Decreasing nitrogen and phosphorus concentrations.* These elements may decrease in plant tissue through the growing season due to high demand during the flowering and seed-forming stages and/or due soil nitrogen depletion.
- *Increasing calcium and magnesium concentrations.* The increases in these elements do not appear to be related to fertilization schedules and suggest instead that they become more available to the plants as the soil warms, rainfall increases, or due to other environmental factors. ZUMA, and possibly the other two farms, also show increasing sulfur concentrations through the season.
- *No consistent trend for potassium concentrations*. In general, it appears that potassium concentrations remain relatively stable in the upper peony leaves throughout the growing season.

A possible effect from two different fertilization approaches may show up in these charts. PEONY applied about twice the amount of granular fertilizer than ZUMA at the beginning of the season whereas ZUMA applied a second fertilization mid-season via fertigation. Although ZUMA's two-stage application system appears to have resulted in more consistent nitrogen concentrations over the growing season, it does not appear to have appreciably maintained the phosphorus concentrations. ZUMA also applied high-phosphorus water soluble fertilizer as a foliar spray before week 8, but without an appreciable increase in the upper leaves.

The concentration trends for the minor elements are not as consistent between the farms as the major elements. Zinc concentrations at the three farms decreased during the season, but the cause is not known. Aluminum and iron increased at PEONY and MERLOT, but not at ZUMA. As with calcium and magnesium, the increases in aluminum and iron may reflect increased availability as the season progresses. In contrast to the other farms, ZUMA iron concentrations were relatively low and manganese concentrations relatively high throughout the season. High manganese levels are known to impede iron uptake and this antagonistic effect may explain the consistently low iron levels at ZUMA.

## Comparisons of 2012 Co-Sampled Upper Leaf, Lower Leaf, and Soil Concentrations

One farm (ZUMA) collected composite samples of both upper and lower leaves and soil approximately every two weeks in 2012. Chart 4 provides individual charts for each nutrient showing the target range for peony leaves and the upper leaf, lower leaf, and soil data from each of the 2012 sampling events.

Based on this set of data, it appears that:

1) The differences between upper and lower leaf concentrations appear negligible for most nutrients.
2) Potassium, aluminum, and iron are the exception to this patterns and appear to have be consistently higher concentrations in bottom leaves.

3) Both mobile and immobile nutrients have similar concentration trends in the upper and lower leaves through the growing season.

4) Co-sampled soil data do not vary directly with the tissue data, most likely due to a time lag between a change in soil concentration and the resultant effect on the plant.

## 2014 Good vs Poor Plants and Soil

In 2014, the project involved collecting two sets of composite soil and tissue samples from Sarah Bernhardt plants and/or Duchesse deNemour peonies from each participating farm. One set was from plants that appeared visually healthy (referred to as "good") and the other set was from plants that did not appear healthy (referred to as "poor"). The purpose in tracking these four data sets was to see if potential nutritional needs could be identified in the tissue and/or soil analytical data. "Good" and "poor" plants are based on a visual evaluation of a plant's health at the time of the sampling event. It does not necessarily signify a superior propensity for increased stem count or bud size, two important factors to peony growers.

Charts 5 thru 8 are graphs used to make these evaluations, and Appendices B and C contain individual charts for each participating grower. Charts 5 and 6 compare the range of nutrient values for all the "good" and "poor" Alaska Duchesse and Sarah plants, respectively, with the target ranges. Chart 7 provides histograms of the entire Alaska 2014 data set, Charts 8 and 9 show regional differences between the good and poor Duchesse and Sarah data sets, respectively, and Appendix D contains a separate report concerning regional differences. Chart 10 compares the change in nutrient ranges for farms that participated in all three of the sampling events for this project (2010, 2012, and 2014). Table 2 summarizes the correlation between the 2014 soil and tissue nutrient concentrations. These data are discussed further in the following sections.

### Comparison of the Average 2014 Good and Poor Tissue Data with Target Ranges

Charts 5 and 6 show that the average nutrient values for the target, good, and poor plants for both Duchesse and Sarah samples. For the most part it appears that both healthy and poor plants have similar nutrient ranges as the target ranges. The average concentration for each nutrient is generally within a factor of two between the groups with only the few exceptions discussed below.

- The good and poor average values for aluminum and iron are approximately half the average target value for both Alaska Duchesse and Sarah plants. The average aluminum value is still within the target range, but the average Alaska iron concentration is even below the target iron range. Alaska soils tend to have relatively low pH and high organic matter levels which typically act to make iron more available. As such, the cause of endemic low iron in Alaska peonies is not known. Since low iron occurs in both good and poor plants, the benefit of adding iron is a topic for further study.
- Poor Sarah plants contained, on average, approximately 50 percent of the target concentrations for calcium, magnesium, boron, and manganese. One or more of these deficiencies may contribute to the poor plant vigor observed in the field.
- Poor Duchesse plants contained, on average, approximately 50 percent of the target boron

concentration, and this may contribute to observed poor plant vigor.

These data suggest that all in all, the nutrient composition of Alaska peony plants are similar to peonies in the lower 48. The individual charts in Appendix B show that in general, each farm has only one or two nutrients that may need to be boosted to enhance the health of their plants.

### 2014 Tissue Histograms

Chart 7 shows histograms for each nutrient and the counts for "good" Duchesse and Sarah Bernhardts and for "poor" Duchesse and Sarah Bernhardts. The first glance at these charts, again, indicate that the range for good and poor plants are almost the same. But if you take a closer look, and think in terms of "the odds", these charts become more informative. Take nitrogen for example. The "odds are" that the more nitrogen in your peony leaves, the better the chances are for your plants to appear healthy. And if your peonies contain less than 2 ppm nitrogen, there's a pretty good chance that your plants will not appear healthy. Boron is another good example, where the odds are pretty good that your plants will not appear healthy if their leaves contains more than 50 ppm boron, but the odds are pretty good that they will look healthy at 40 ppm boron.

### Correlation Between 2014 Soil and 2014 Tissue Data

To evaluate whether soil concentrations correlate with the health of the plant, soil:plant correlations were calculated. Correlations identify the tendency for a variable (in this case, the plant concentration) to change in value as another variable (soil concentration) changes in value. A correlation of 1 means that the plant's nutrient concentration correlates exactly with the soil's concentration (e.g., as the soil concentration increases, the plant concentration increases). A correlation of 0 means that no correlation exists between the nutrient's soil concentration and the plant concentration. Values between 0 and 1 show an increasing tendency for the soil and plant concentrations to vary together.

Table 2 summarizes the results of these calculations for the 2014 samples. The column called "All Plants" shows the correlation between each nutrient's concentration in a soil sample with the corresponding plant sample for all 2014 samples. In general, the data show only a weak correlation between the soil and plant concentrations for all of the nutrients; the highest correlation is 0.55 for aluminum.

Additional correlations shown on Table 3 were calculated between the following data sets:

- "good Duchesse plants" and "good Duchesse soil"
- "good Sarah plants" and "good Sarah soil"
- "poor Duchesse plants" and "poor Duchesse soil"
- "poor Sarah plants" and "poor Sarah soil".

Of all the analytes, only aluminum had correlations above 0.5 for all four data sets. One interesting observation is that the soil magnesium concentration is strongly correlated with the plant magnesium concentration in Sarahs (correlation >0.8) but not in Duchesse (correlation <0.45).

These calculated correlations agree with the soil data included on Chart 4 where a visual inspection shows that soil concentrations do not vary consistently with changes in leaf concentrations. What this means to the peony farmer is that a single soil analysis is of limited value for assessing problems associated with unhealthy plants at any specific point in time. Yearly data and careful record keeping will be of much greater value to assess a changed soil condition and its subsequent impact on plant health.

## REGIONAL COMPARISONS

Charts 8 and 9 show potential regional differences in the nutrient make up of Duchesse and Sarah peony plant tissue, respectively, based on the 2014 data. Appendix D contains a detailed report discussing regional differences in both soil and peony tissue data.

The nutrient concentrations in peony tissue, especially for nitrogen, demonstrate a fairly even range for both good and poor sites for both the Sarah Bernhardt and Duchess cultivars. For example, in the MatSu area, the good sites had a tissue nitrogen concentration of 2.23% for the Sarah Bernhardt cultivar and 2.10% for the Duchess cultivar. In contrast, the poor sites only had a nitrogen concentration of 1.75% for the Sarah Bernhardt cultivar and 1.65% for the Duchess cultivar. For the interior and Kenai Peninsula, the difference between good and poor sites in terms of nitrogen concentration was narrow. However, that was most likely due to a higher supply of nutrients from the soil in the interior and Kenai Peninsula. The potassium concentrations appear to be negatively related to the nitrogen concentration in peony tissue, meaning high nitrogen concentrations are accompanied by low potassium concentrations in the peony tissue. For phosphorus, there is no clear trend.

For the micronutrient concentrations in the peony tissue, a high calcium concentration is associated with the good sites in all three regions for both cultivars. Since calcium can enhance the cell wall strength, the high nitrogen in the peony tissue corresponding with the high calcium concentration was good for plant growth for all growers in all regions. The magnesium and boron concentrations also correspond with the good and poor sites, meaning the good sites had higher apparent magnesium and boron concentrations in tissues than did the poor sites. For zinc and copper, the gap between the good and poor sites is not as large as for the other micronutrients. However, for the iron concentration, there is a large gap between the good and poor sites, especially for the Sarah Bernhardt cultivar. Iron is an essential element for chlorophyll production. The high iron concentration in tissue helps the photosynthesis process of the peony plants.

## COMPARISON OF 2010-2012-2014 PARTICIPANTS DATA

Chart 10 summarizes data for the five farms that participated in all three years of the field studies, and Appendix C contains separate charts for each of these participants. The data on Chart 10 suggest that the concentration ranges have improved over the years as the peonies have matured, with nutrient ranges

becoming tighter and increasingly similar to the target ranges except for aluminum, iron, and manganese. The Alaska concentration ranges for these three elements extend below the target ranges and their averages are about half of the target averages.

# DISCUSSION

## LESSONS LEARNED

1. Co-sampled soil nutrient data are only weakly correlated, if at all, with the nutrient content of peony leaves. This finding may be unexpected, but it is consistent with the findings in the first phase of this project. The report from the 2010 study indicates that low phosphorus conversion from soil to tissue and low to moderately-low boron conversion from soil to tissue are potentially significant problems in Alaska fields. This is not to imply that soil data are not important, but rather to stress that regular soil sampling will be of more use to the grower.

2. Both mobile and immobile nutrients have similar concentration trends in the upper and lower leaves through the growing season, and based on our 2012 data, little additional information is gained by collecting samples from both sets of leaves. This finding is based on samples from one field for one growing season, and it may be advisable to confirm this finding in future studies.

3. Overall, 2014 samples from Alaska peony leaves have similar nutrient content as lower 48 peony leaves except possibly for aluminum, iron, and manganese. Individual farms have other deficiencies and/or excesses.

4. Sarah plants appear to have a greater tendency for nutrient deficiencies than the Duchesse variety based on the 2014 data.

5. The approach for conducting both phases of this project was modified each year which, although not ideal or preferable from a consistency standpoint, has resulted in improved methodology if APGA continues their nutritional studies. For future work, it is important to a) have one person collect all the samples, if possible, to promote consistency and completion, b) sample and track healthy and not-healthy plants separately, and c) sample and track by variety if possible. Continuing to collect Outside data may not be necessary as the Alaska plants have matured to a point where healthy Alaska peonies can be confidently identified.

## PROJECT BENEFICIARIES

The findings from this project are of benefit to all the Alaska peony growers, but most especially to the growers who participating in the sampling events. The participants have a base from which to continue their long-term monitoring of their fields, and non-participants have a blueprint for evaluating their fields. Each

grower can compare sample results from their own peony fields with data from other healthy peonies, from both Outside and Alaska peonies.

## PROJECT SUPPORT

APGA would like to thank the Alaska Division of Agriculture for their support in funding this project.

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**Table 1**. Range and Average Concentrations from Lower 48 Peony Plant Tissue Samples

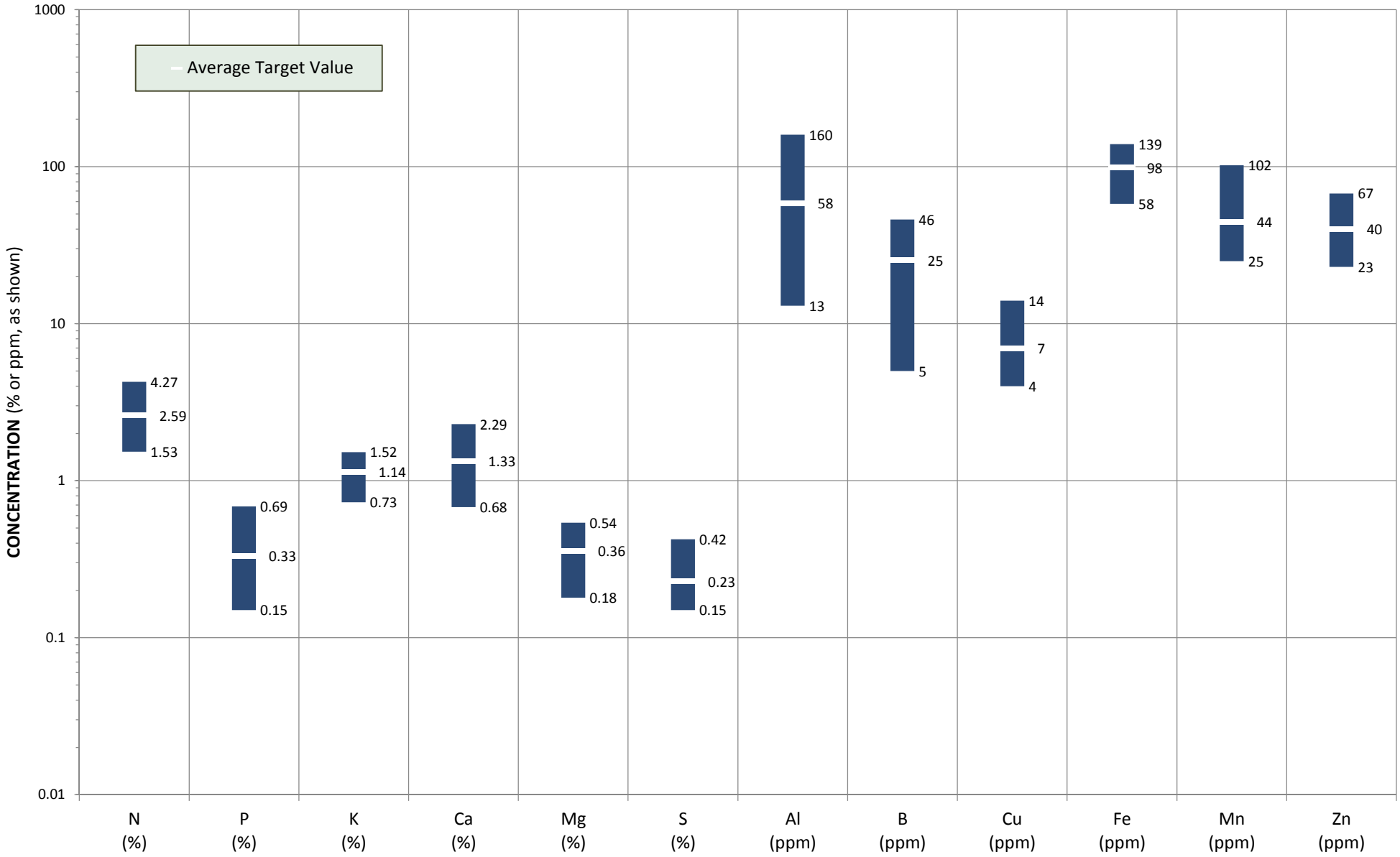
| Nutrient | High Concentration | Low Concentration | Average Concentration |
|---|---|---|---|
| N (%) | 4.3 | 1.5 | 2.6 |
| P (%) | 0.69 | 0.15 | 0.33 |
| K (%) | 1.5 | 0.73 | 1.1 |
| Ca (%) | 2.3 | 0.68 | 1.3 |
| Mg (%) | 0.54 | 0.18 | 0.36 |
| S (%) | 0.42 | 0.15 | 0.23 |
| Al (ppm) | 160 | 13 | 58 |
| B (ppm) | 46 | 5.0 | 25 |
| Cu (ppm) | 14 | 4.0 | 7.0 |
| Fe (ppm) | 139 | 58 | 98 |
| Mn (ppm) | 102 | 25 | 44 |
| Zn (ppm) | 67 | 23 | 40 |

**Table 2**. Correlations between 2014 Co-Sampled Soil and Leaf Analyses

| | All Plants | Duchesse - Good | Sarah - Good | Duchesse - Poor | Sarah - Poor |
|---|---|---|---|---|---|
| Nitrogen (Soil ppm/Tissue %) | 0.24 | 0.46 | 0.31 | 0.06 | 0.21 |
| Phosphorus (Soil ppm/Tissue %) | 0.32 | 0.43 | 0.17 | 0.16 | 0.56 |
| Potassium (Soil ppm/Tissue %) | 0.23 | 0.65 | 0.20 | 0.32 | 0.11 |
| Calcium (Soil ppm/Tissue %) | 0.11 | -0.04 | 0.36 | 0.26 | 0.46 |
| Magnesium (Soil ppm/Tissue %) | 0.45 | 0.42 | 0.80 | 0.35 | 0.87 |
| Sulfur (Soil ppm/Tissue %) | 0.14 | 0.06 | 0.17 | 0.25 | 0.02 |
| Aluminum (Soil ppm/ Tissue ppm) | 0.55 | 0.58 | 0.50 | 0.62 | 0.51 |
| Boron (Soil ppm/ Tissue ppm) | 0.34 | 0.26 | 0.36 | 0.45 | 0.41 |
| Copper (Soil ppm/ Tissue ppm) | 0.15 | 0.39 | 0.11 | 0.38 | 0.15 |
| Iron (Soil ppm/ Tissue ppm) | 0.11 | 0.12 | 0.14 | 0.14 | 0.13 |
| Manganese (Soil ppm/ Tissue ppm) | 0.06 | 0.42 | -0.20 | 0.33 | -0.07 |
| Zinc (Soil ppm/ Tissue ppm) | 0.27 | 0.36 | 0.34 | 0.05 | 0.61 |

> 0.5 correlation

**Chart 1.** Range and Average Concentrations from Lower 48 Peony Plant Tissue Samples




Blue vertical bars represent the range of values in tissue samples from Outside Growers' plants, 2010 - 2014.

**Chart 2.** Comparison of 2010 and 2012 Bottom Leaf Analyses

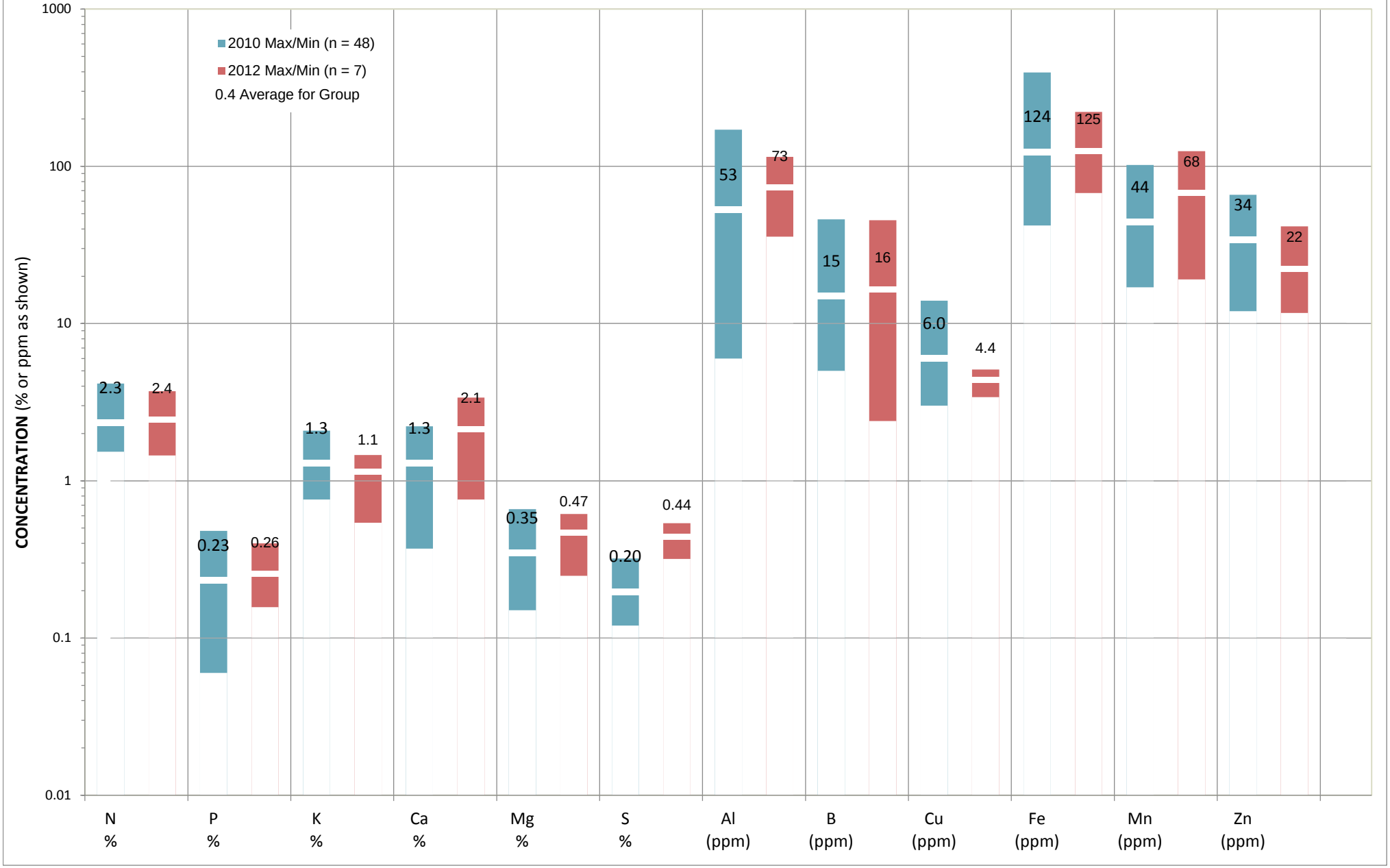
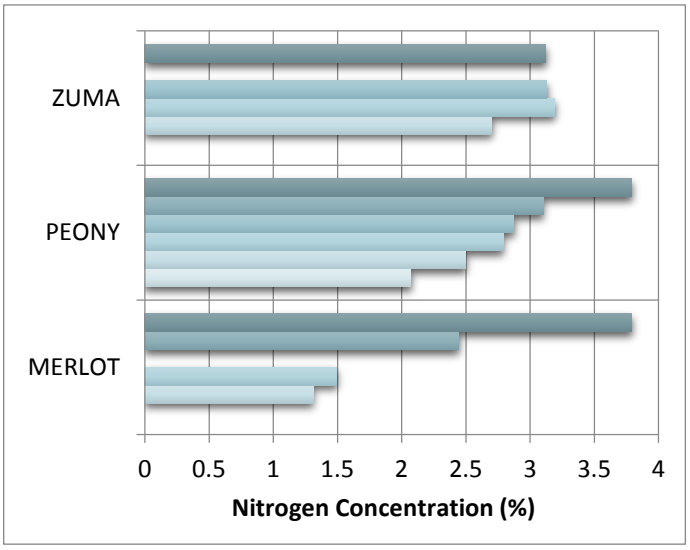
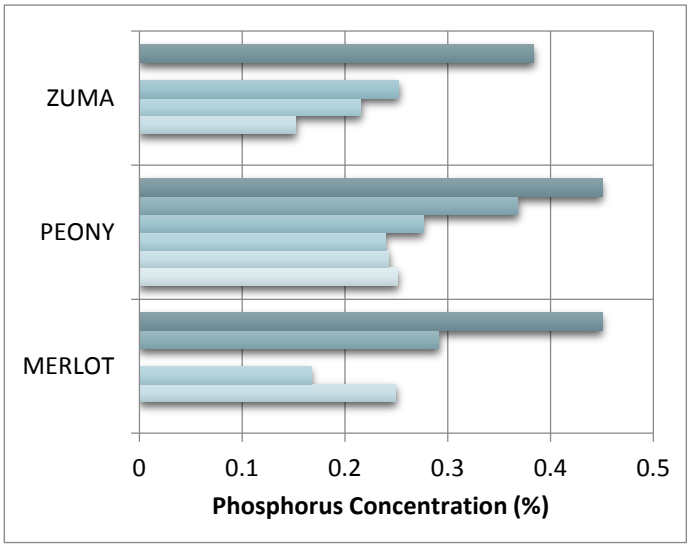
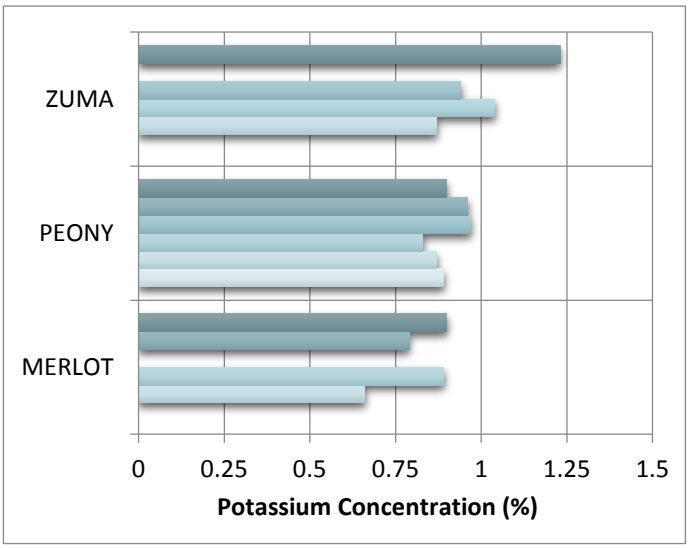
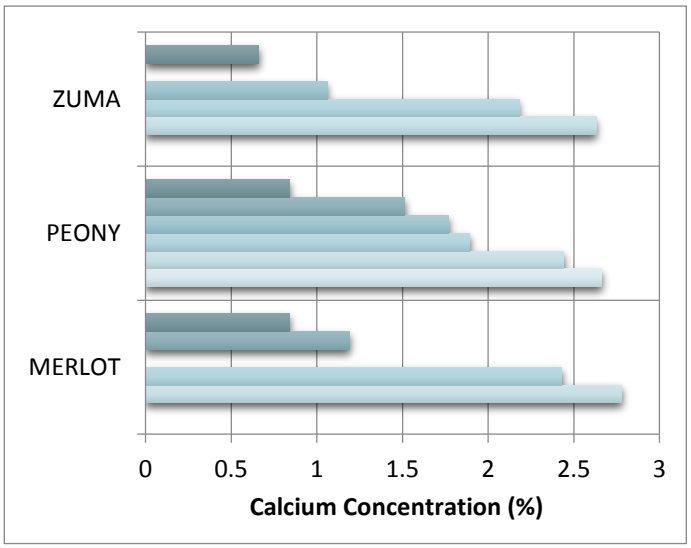


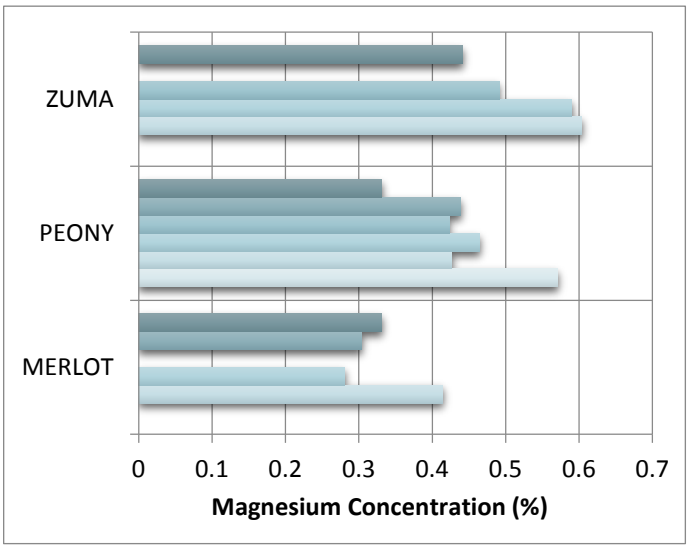
**Chart 3**. Upper Leaf Analyses from Three Farms, Week 0 to Week 10, 2012

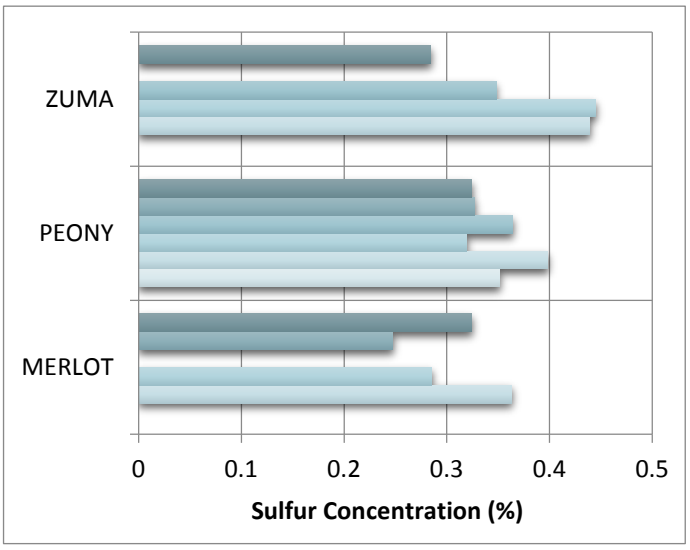


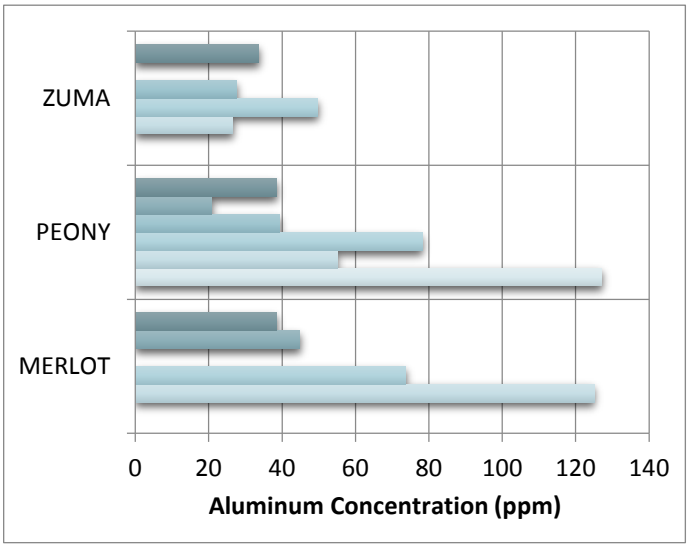



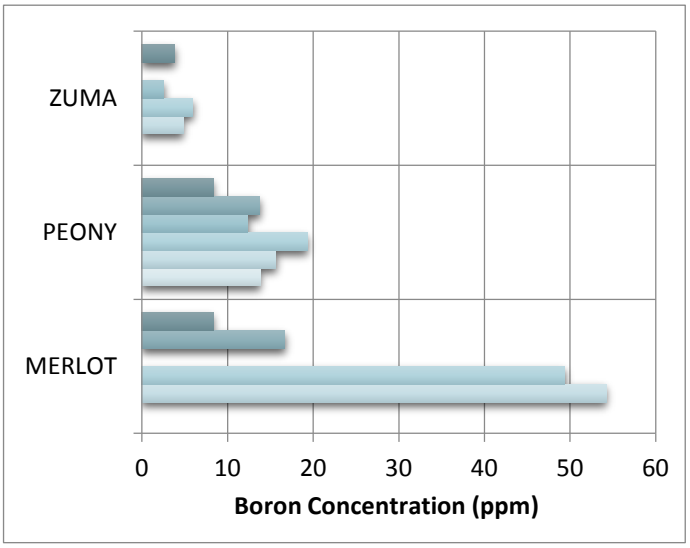



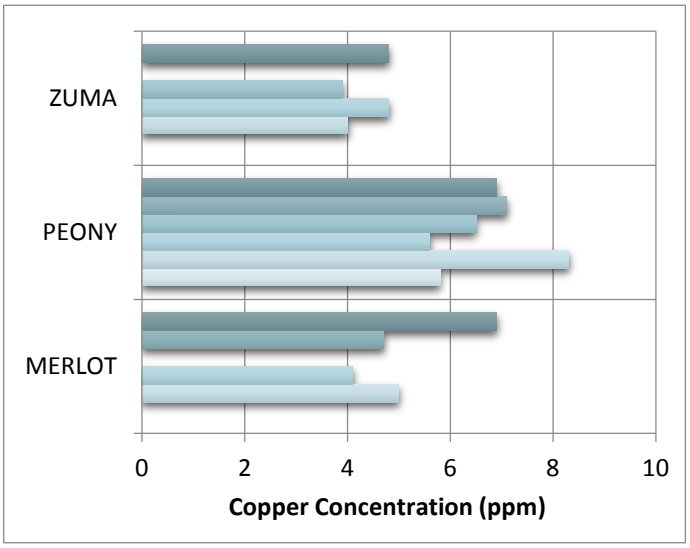



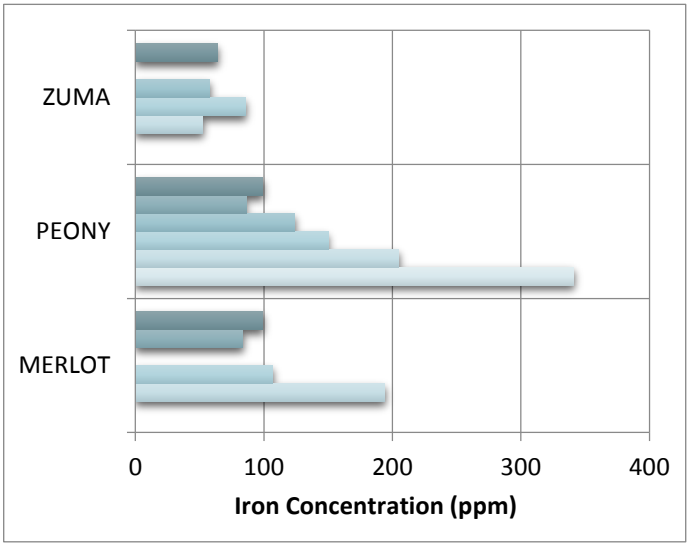

WEEK 0 WEEK 2 WEEK 4 WEEK 6 WEEK 8 WEEK 10

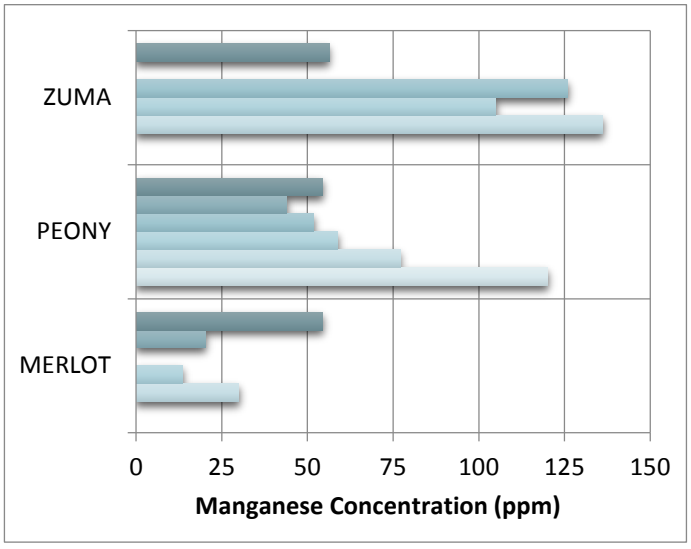
**Chart 3 (cont'd)**. Upper Leaf Analyses from Three Farms, Week 0 to Week 10, 2012

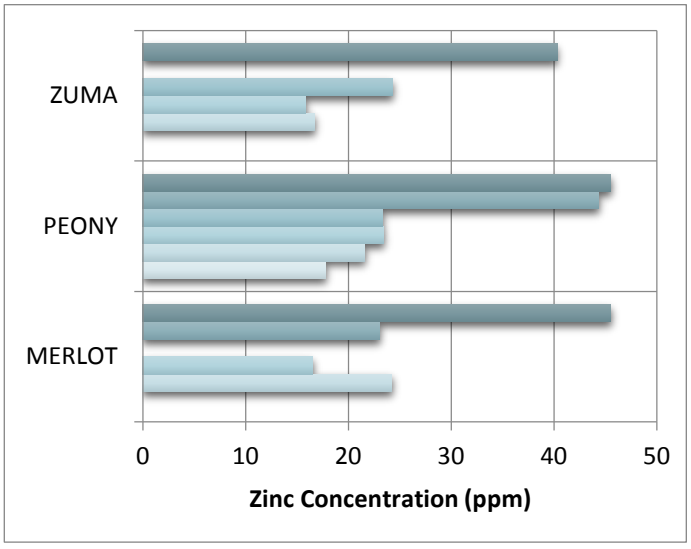


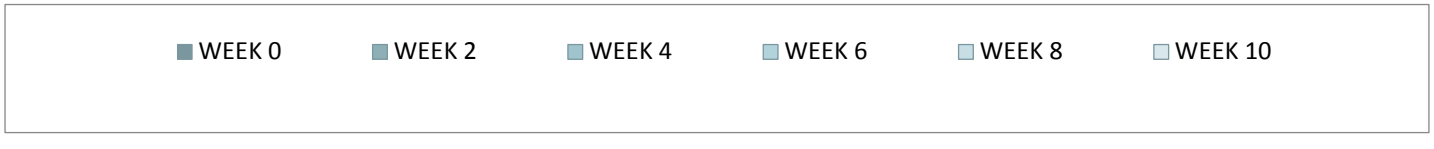



**Chart 4**. 2012 Upper Leaf, Lower Leaf, and Soil Analyses from ZUMA Duchesse Field

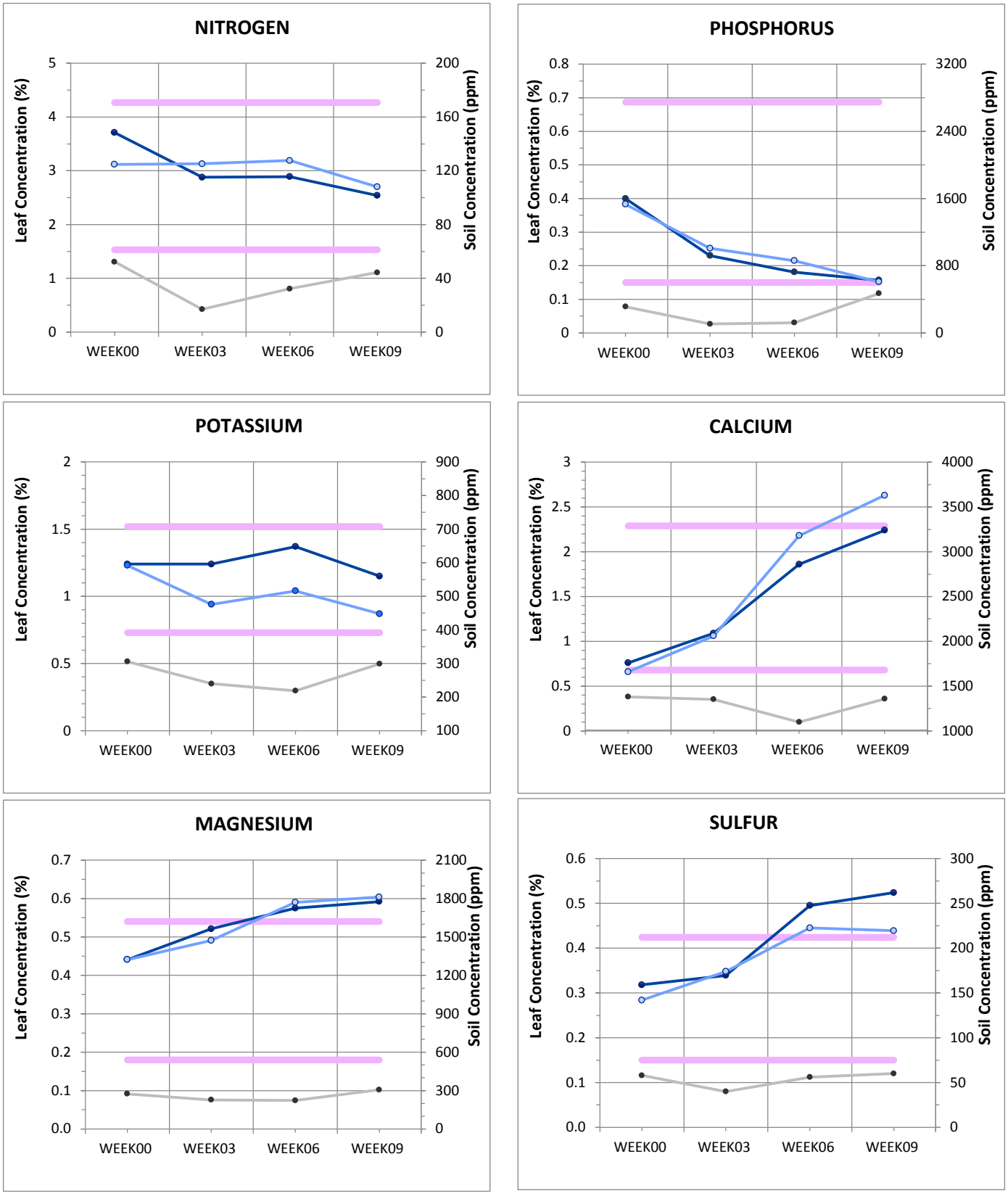


**Chart 4 (cont'd)**. 2012 Upper Leaf, Lower Leaf, and Soil Analyses from ZUMA Duchesse Field

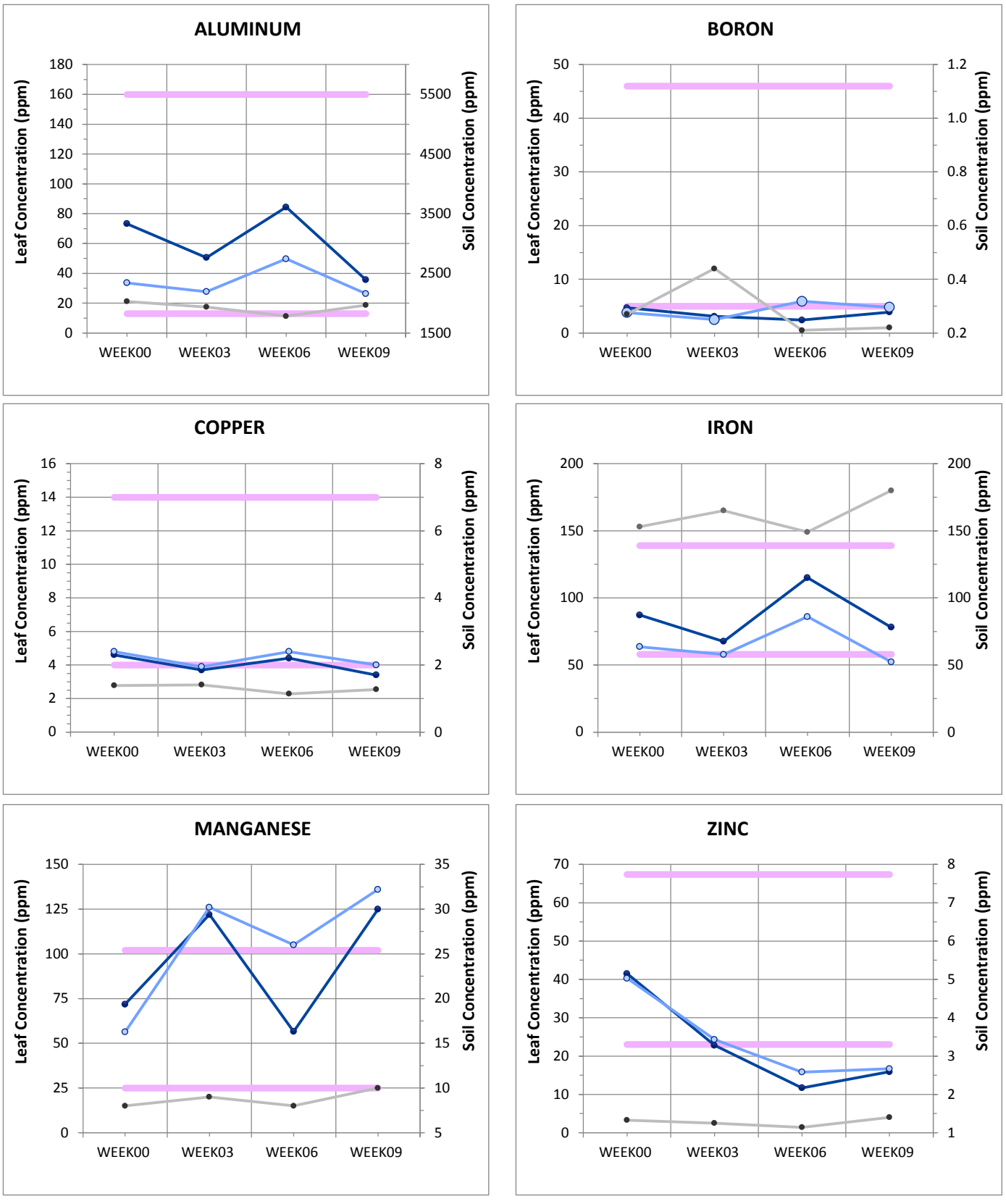


**Chart 5.** 2014 Nutrient Concentrations in 'Good' & 'Poor' Duchesse deNemour Peony Leaves - Major Nutrients

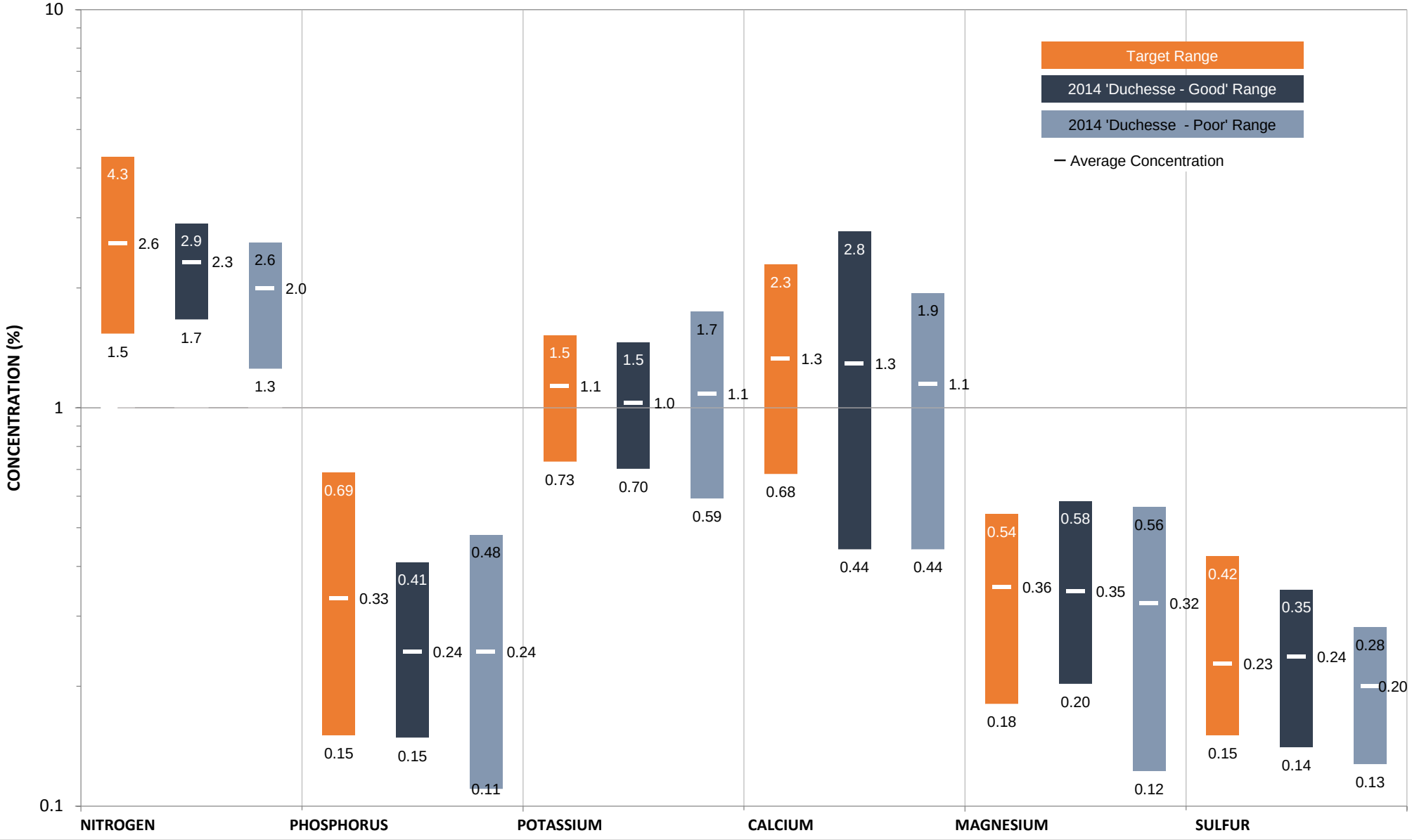


**Chart 5.** 2014 Nutrient Concentrations in 'Good' & 'Poor' Duchesse deNemour Peony Leaves - Minor Nutrients


2010-2014 TISSUEDATA.XLS/SARAHB GOOD-POOR

**Chart 6.** 2014 Nutrient Concentrations in 'Good' & 'Poor' Sarah Bernhardt Peony Leaves - Major Nutrients

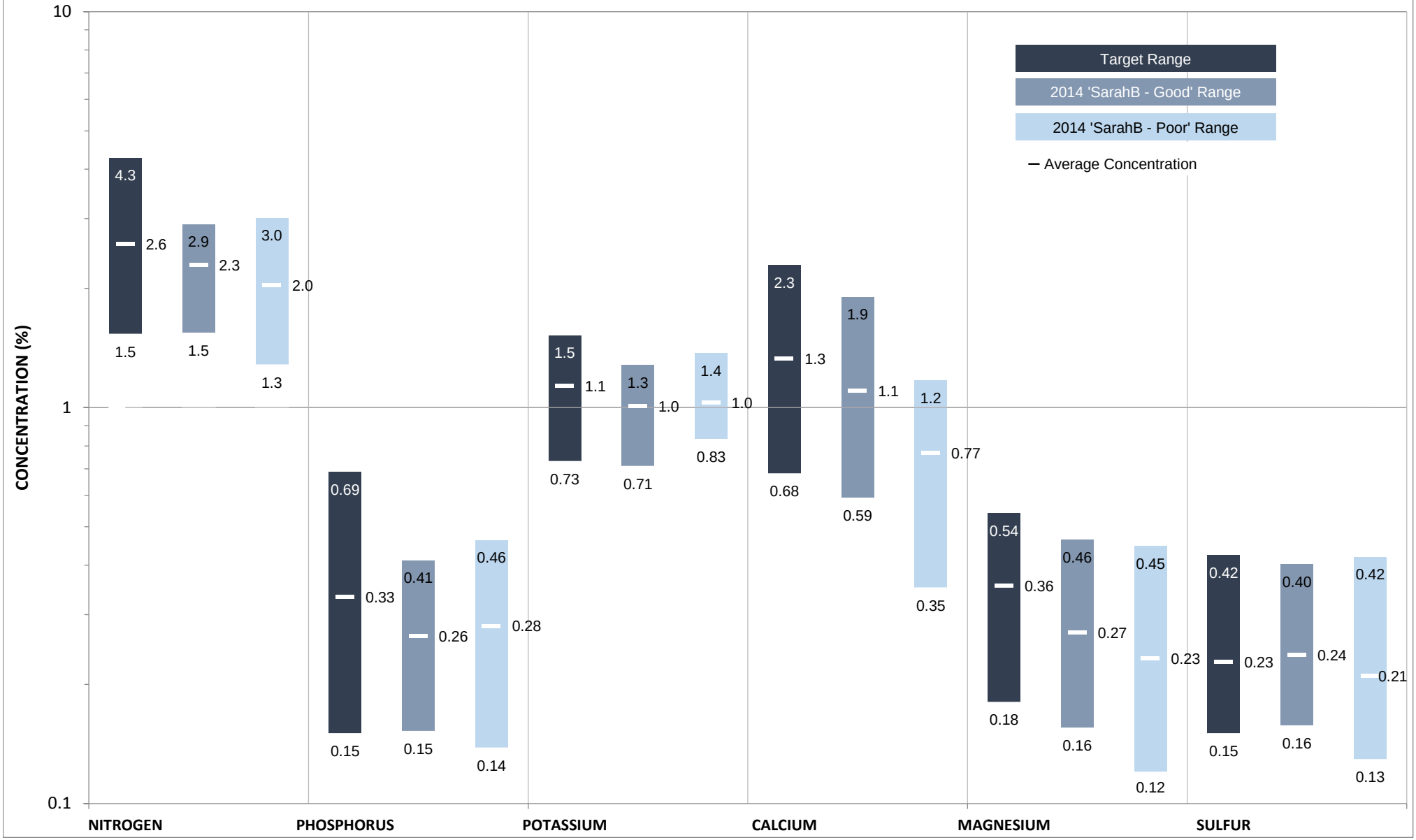


**Chart 6.** 2014 Nutrient Concentrations in 'Good' & 'Poor' Sarah Bernhardt Peony Leaves - Major Nutrients

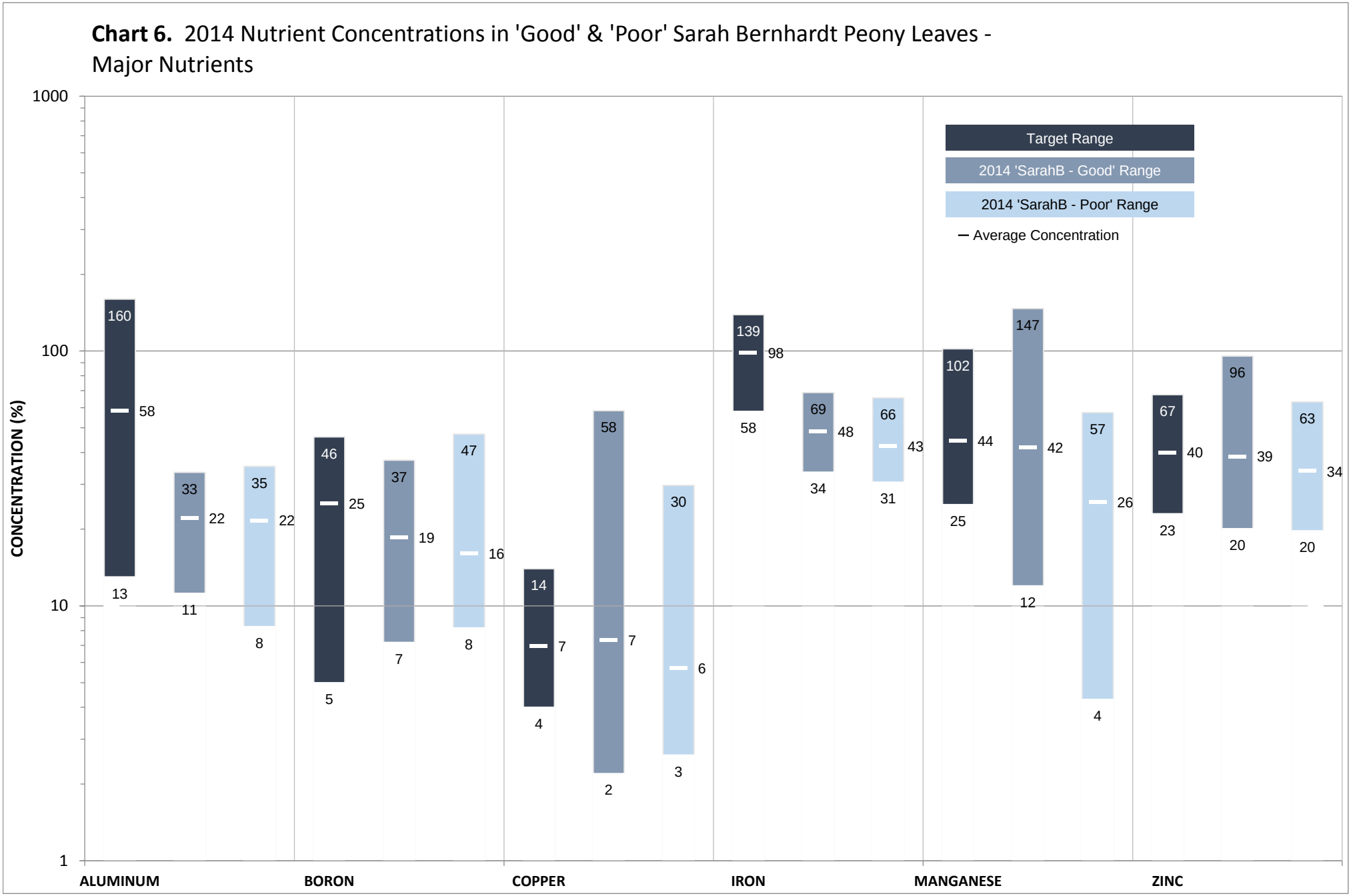


**Chart 7.** 2014 Tissue Histograms

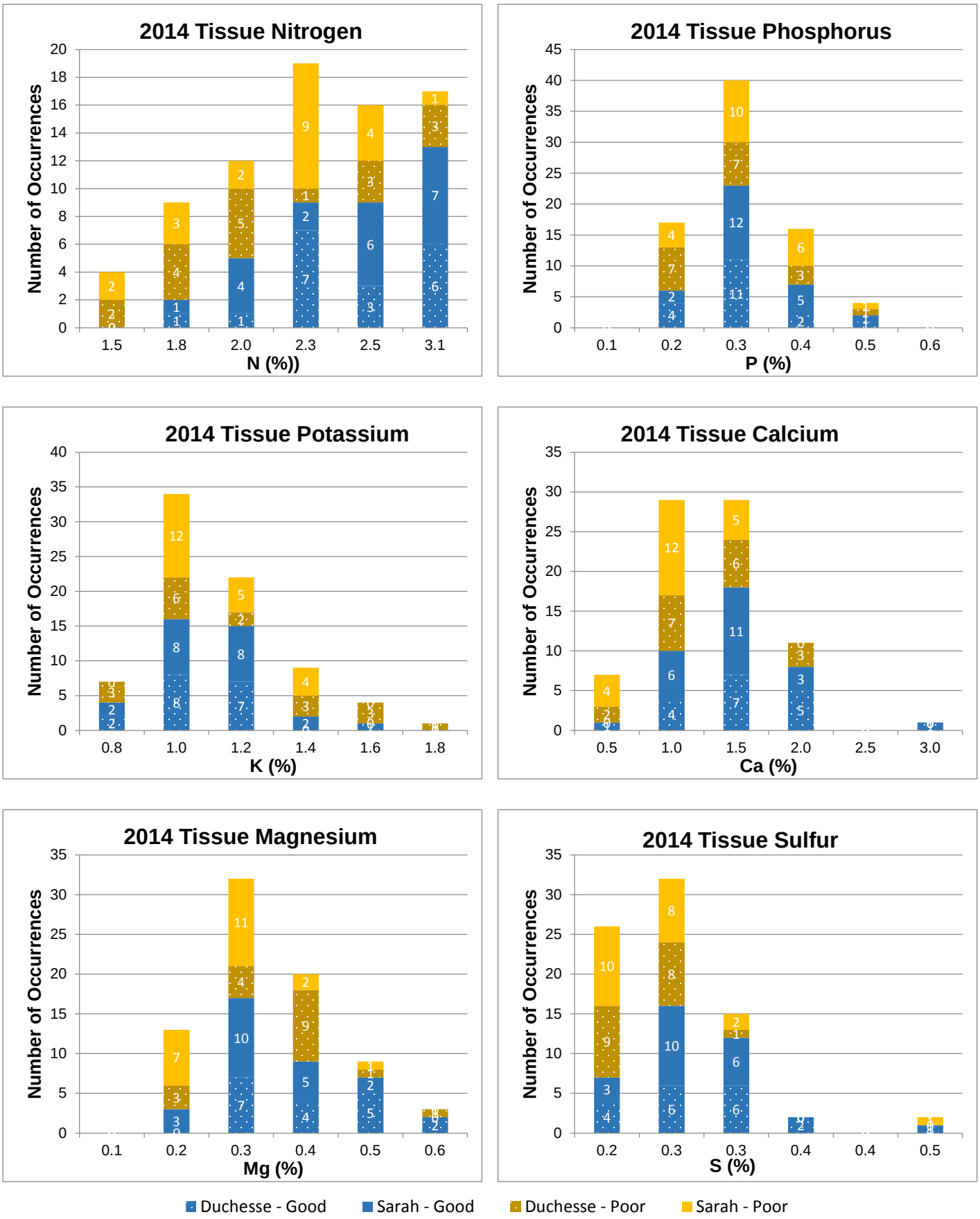
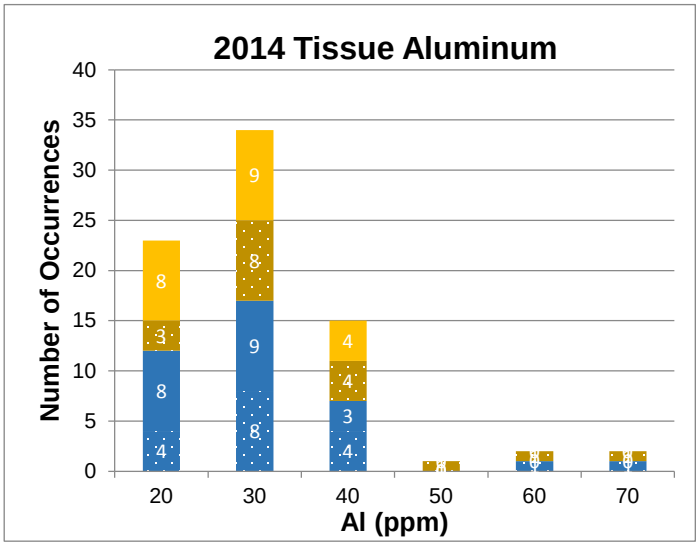
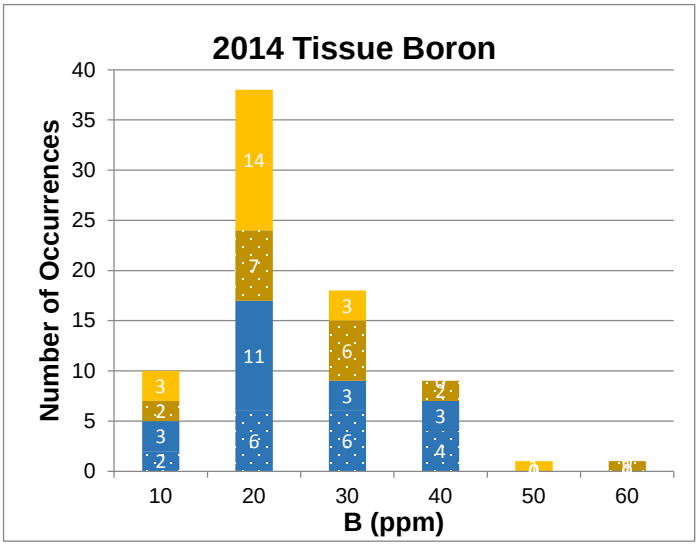
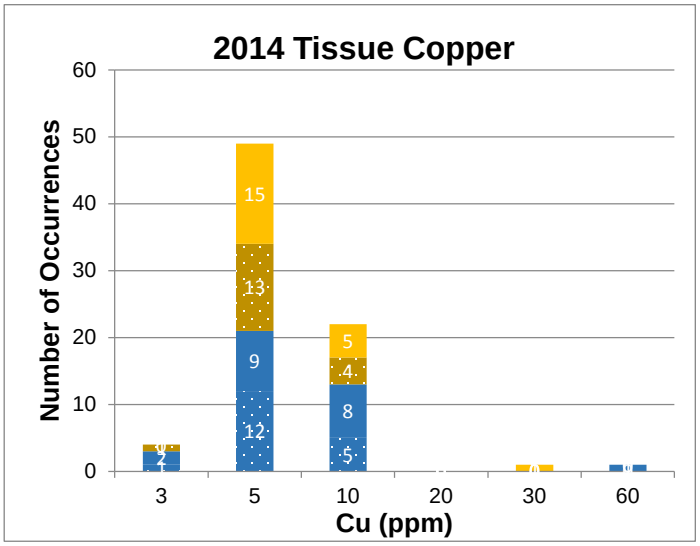
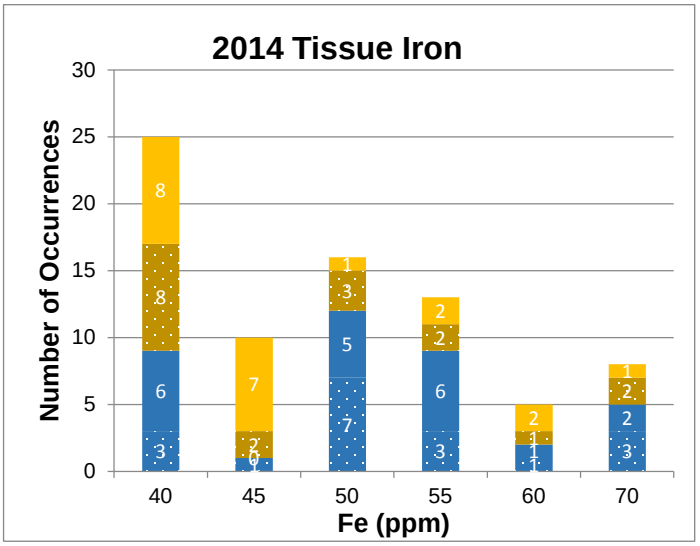


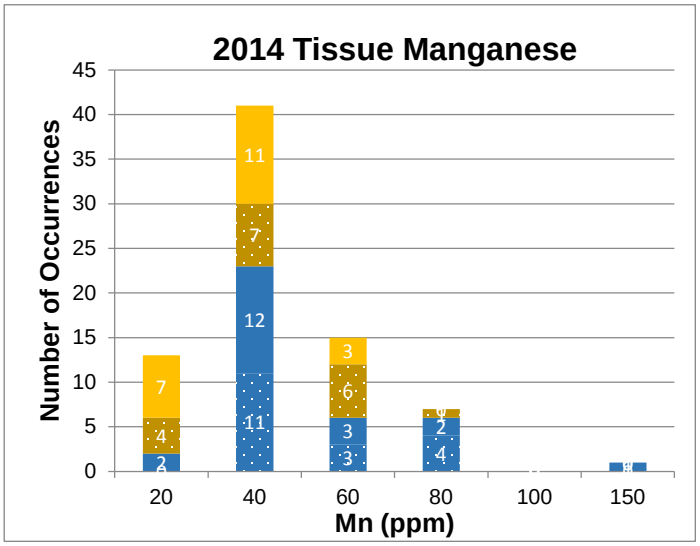
**Chart 7 (cont'd).** 2014 Tissue Histograms

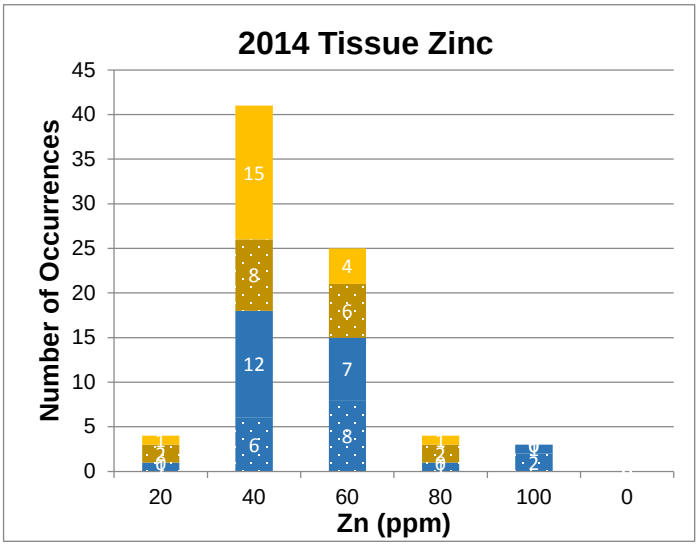



Duchesse - Good  Sarah - Good  Duchesse - Poor  Sarah - Poor

**Chart 8.** Regional Differences in Duchesse deNemour Peony Tissue Samples - Major Nutrients

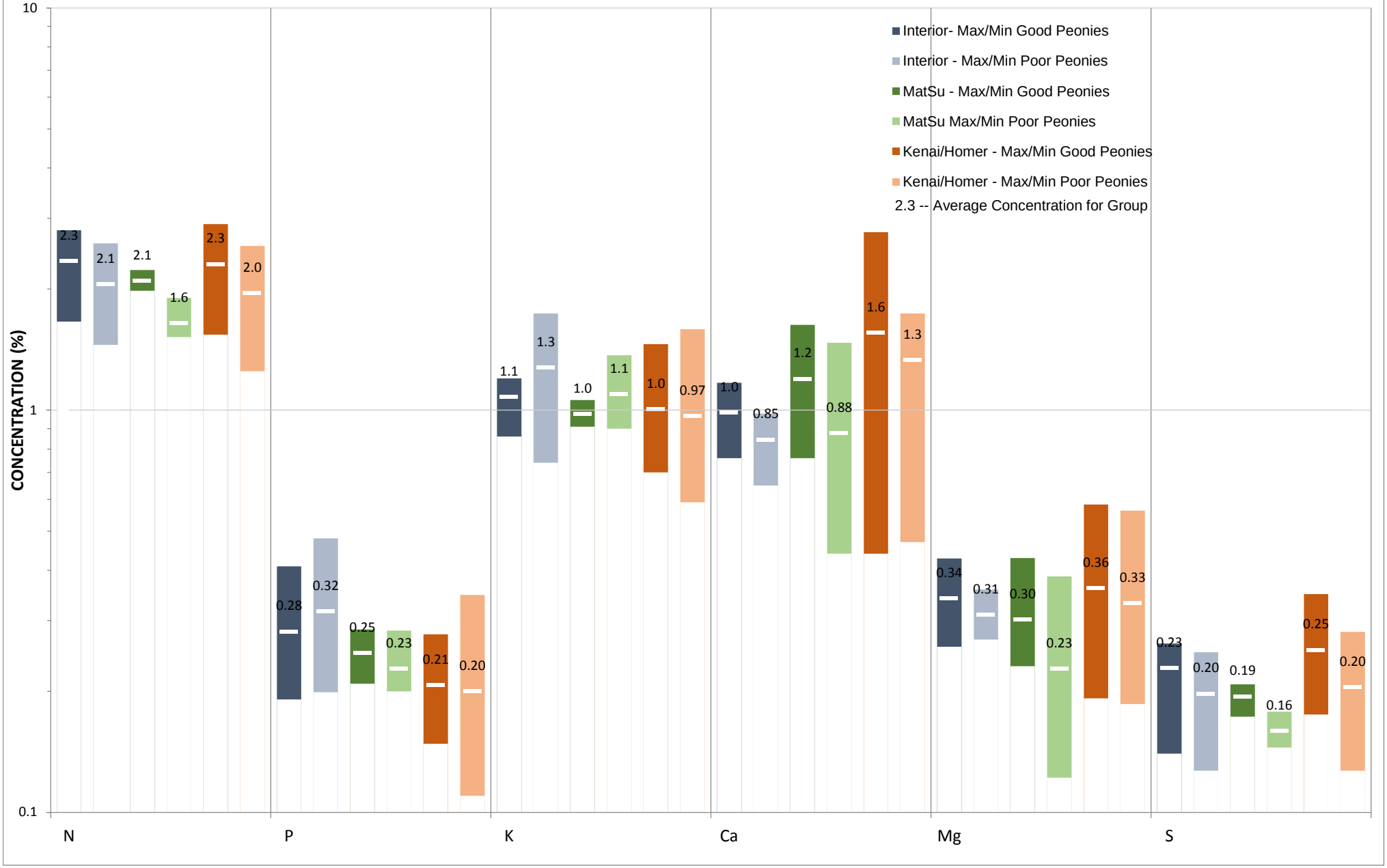
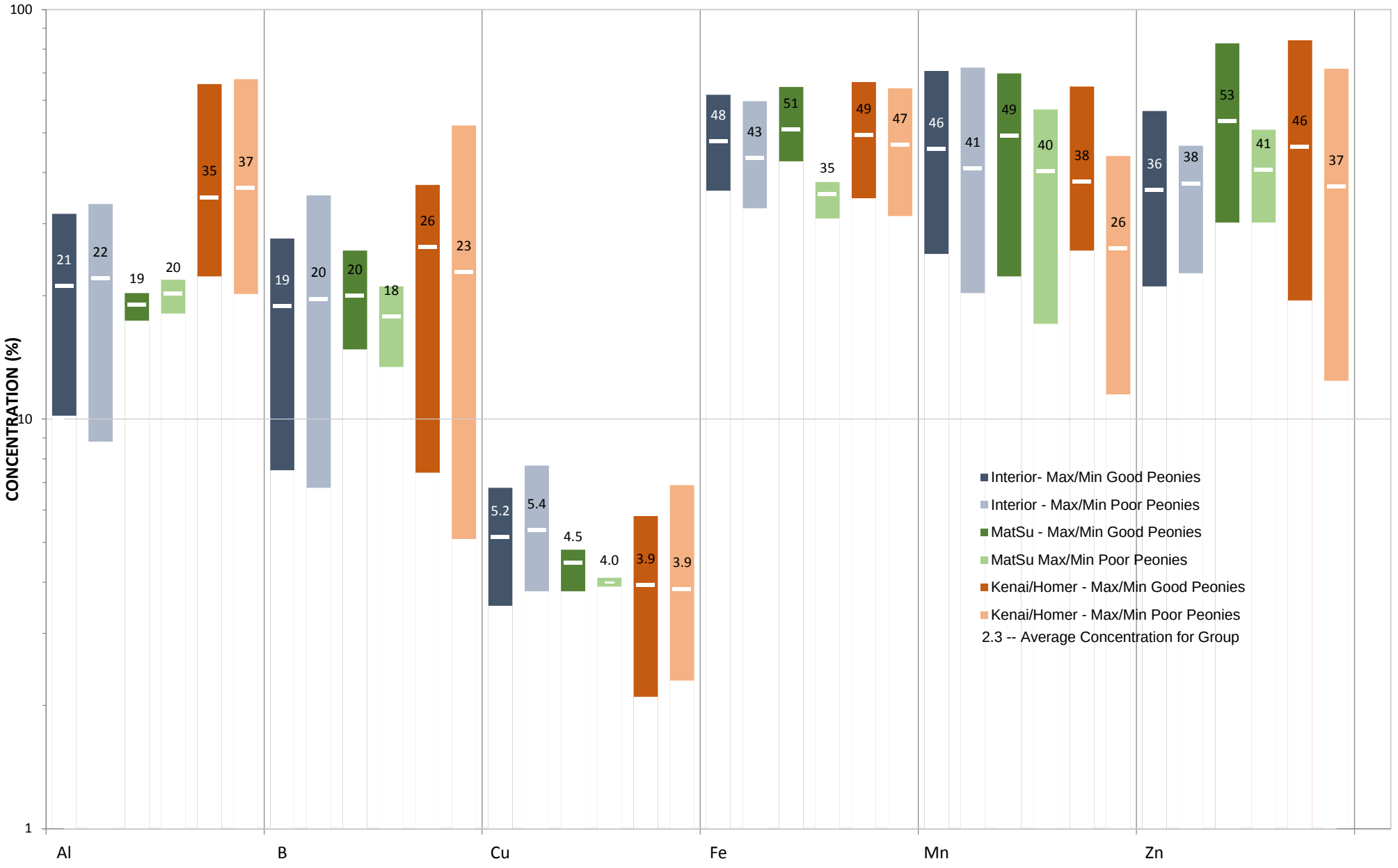
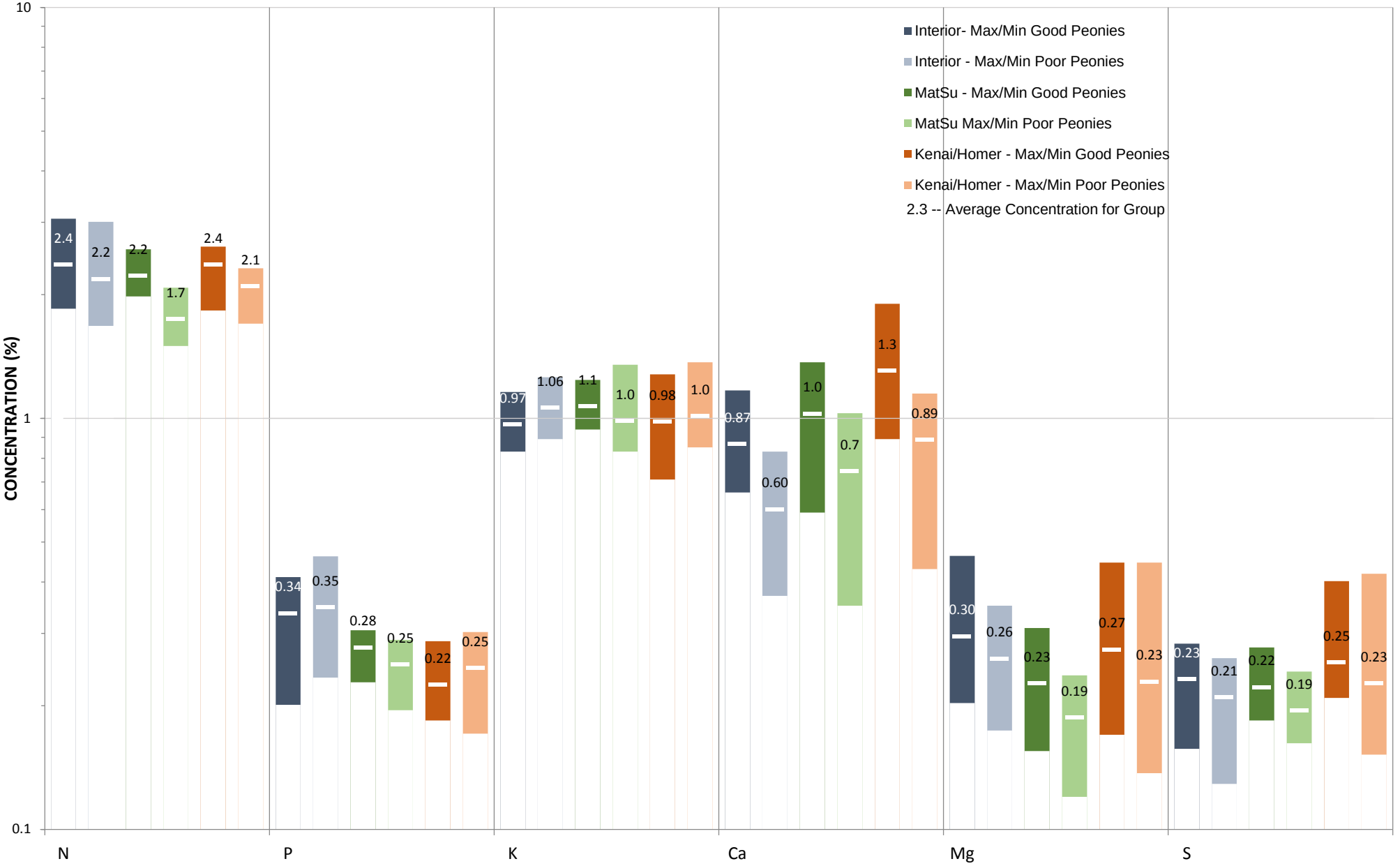


**Chart 8.** Regional Differences in Duchesse deNemour Peony Tissue Samples - Minor Nutrients




2014 REGIONALTISSUE.XLSX/SARAHB

**Chart 9.** Regional Differences in Sarah Bernhardt Peony Tissue Samples - Major Nutrients




2014 REGIONALTISSUE.XLSX/SARAHB

**Chart 9.** Regional Differences in Sarah Bernhardt Peony Tissue Samples - Minor Nutrients

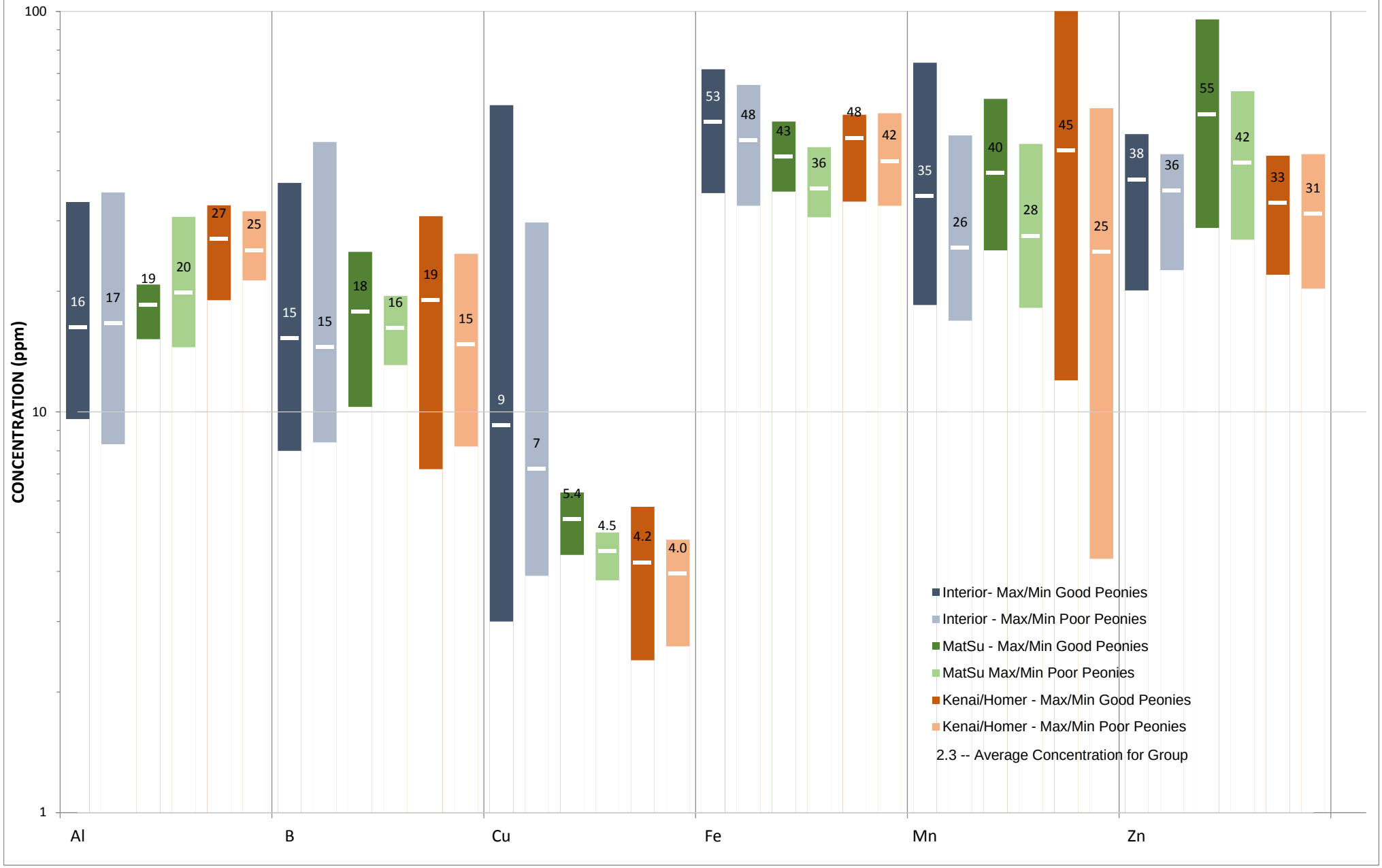
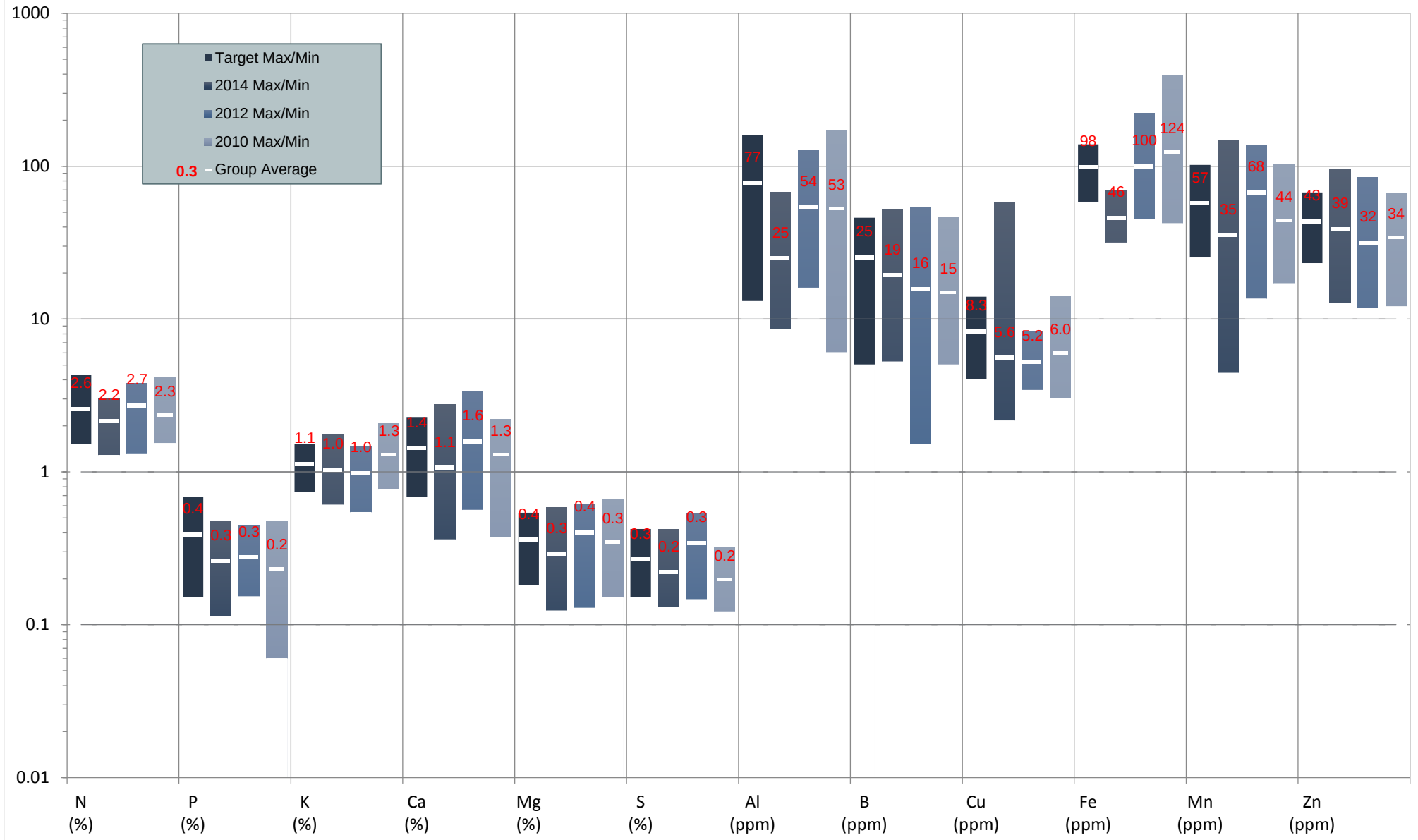
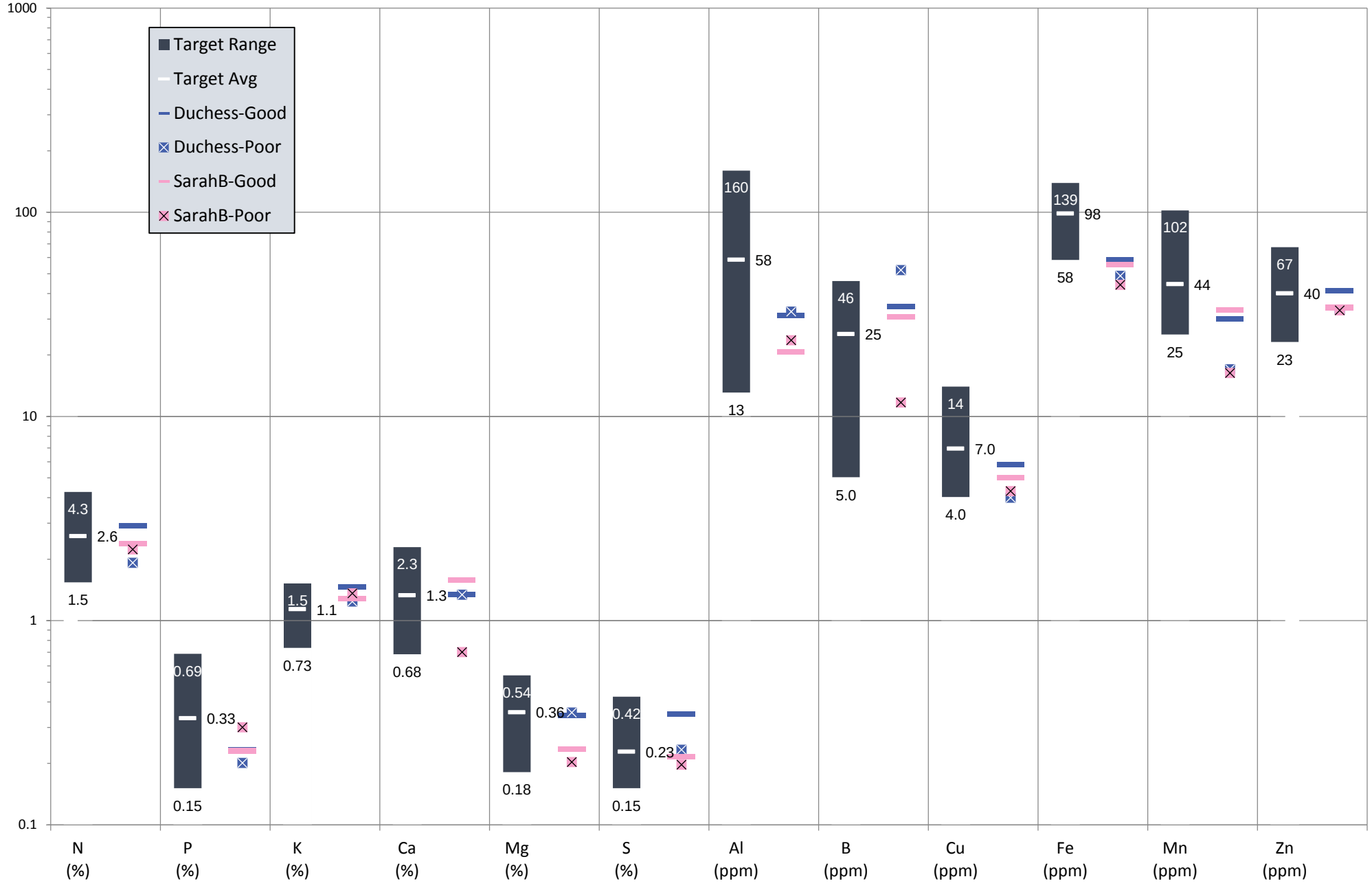


**Chart 10.** Summary Data for 2010-2012-2014 Participants



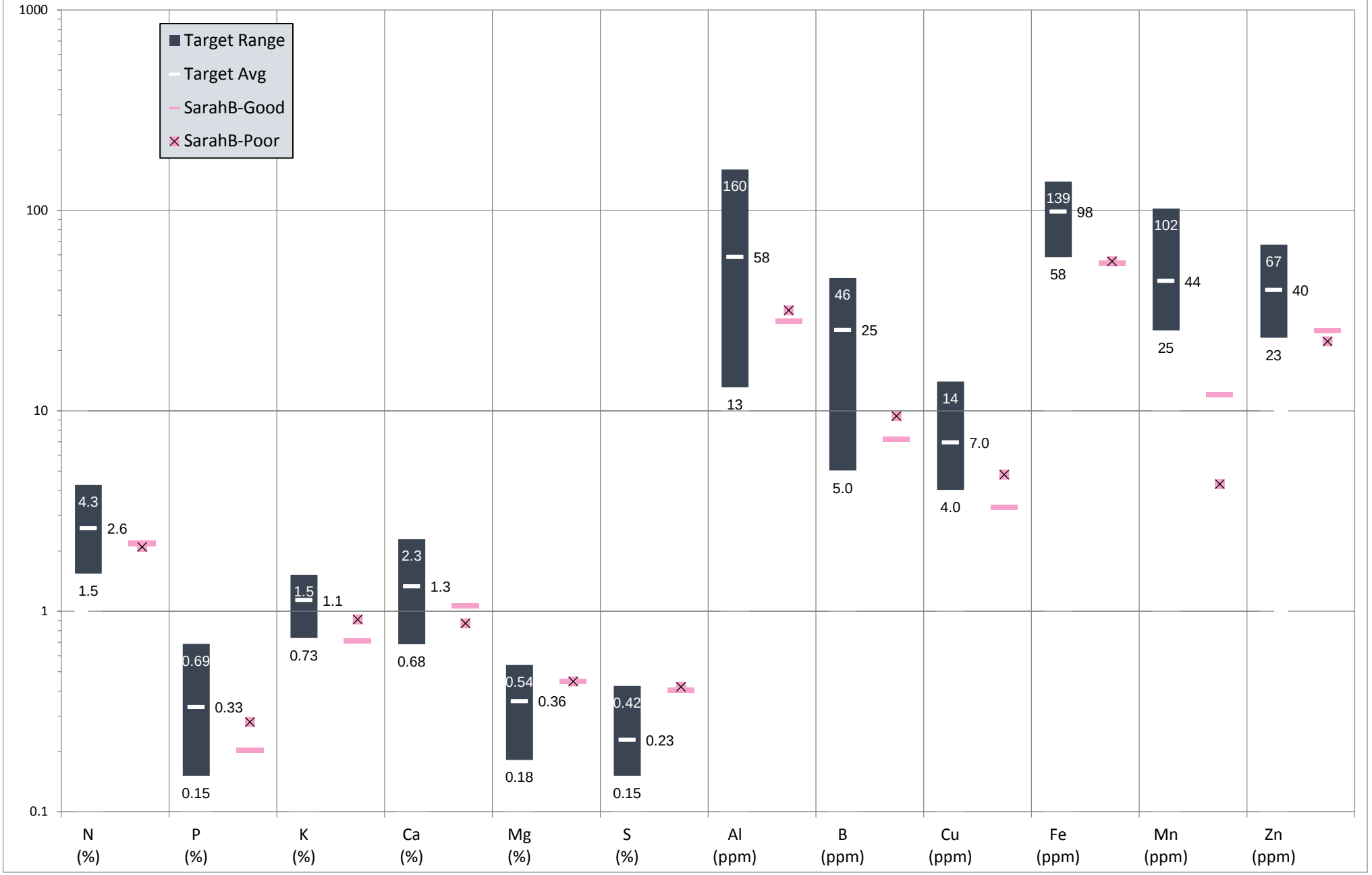
## 2014 Tissue Data Compared to Target Ranges

**Grower 3**



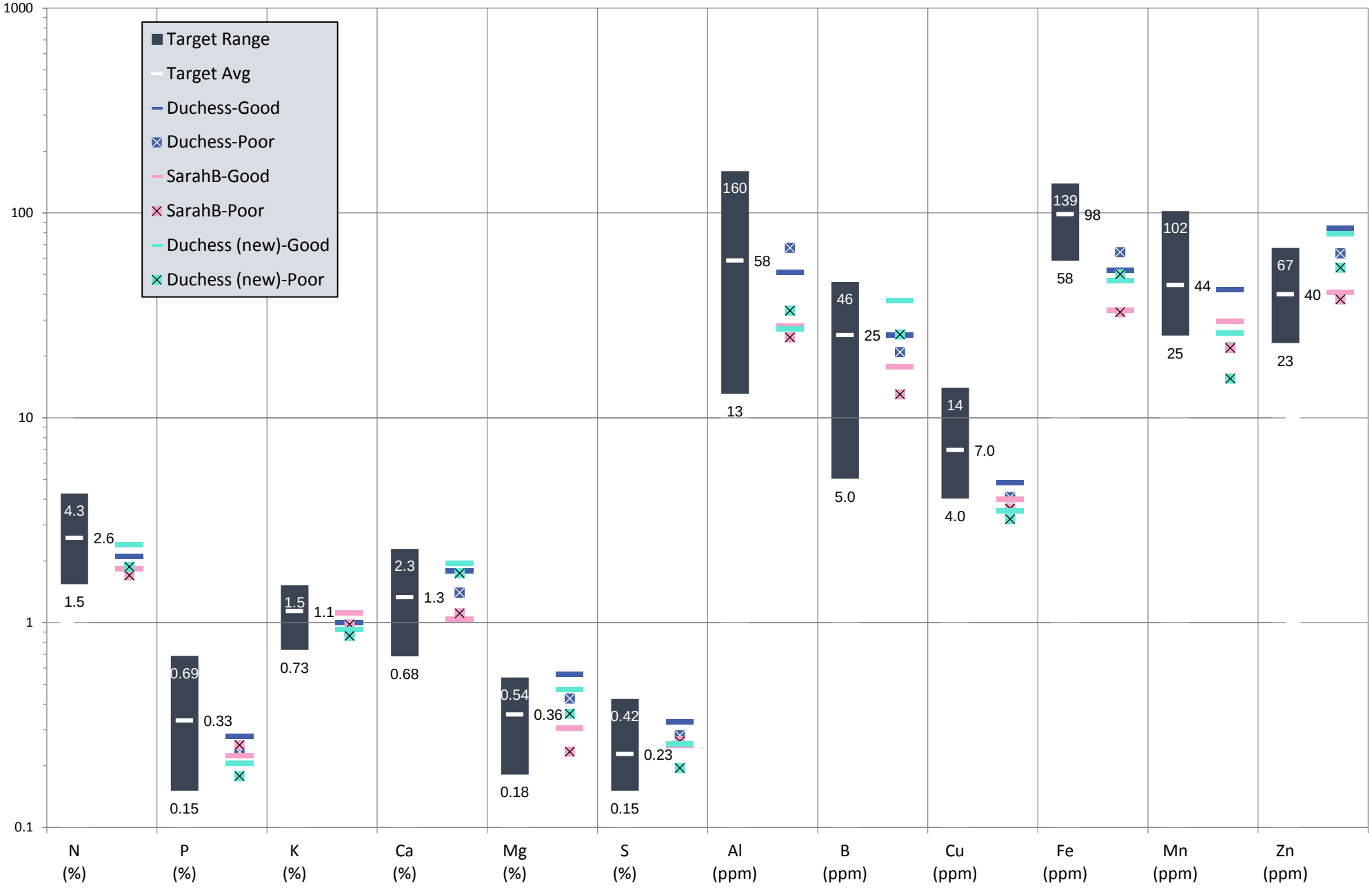
## 2014 Tissue Data Compared to Target Ranges

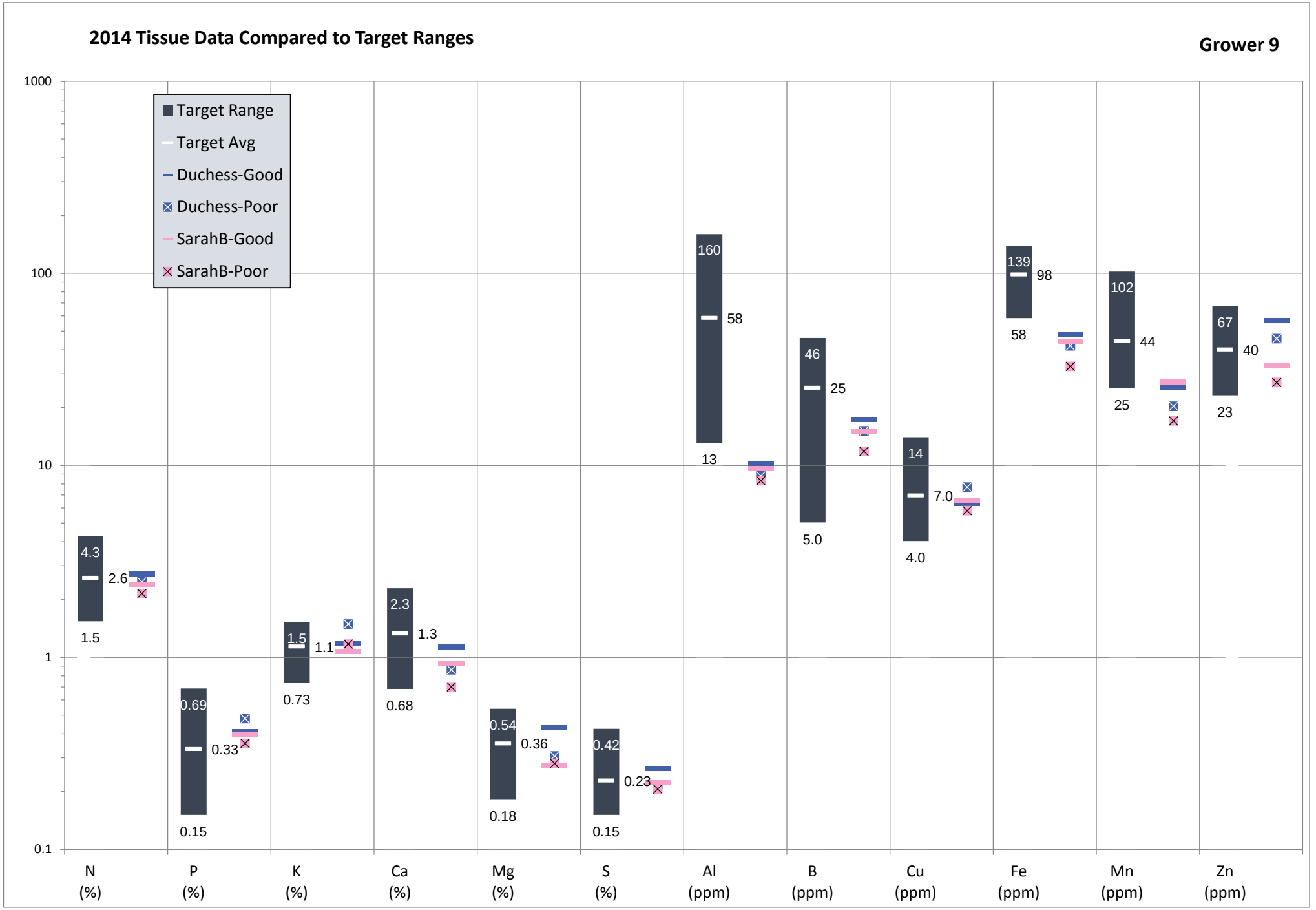
**Grower 5**



## 2014 Tissue Data Compared to Target Ranges

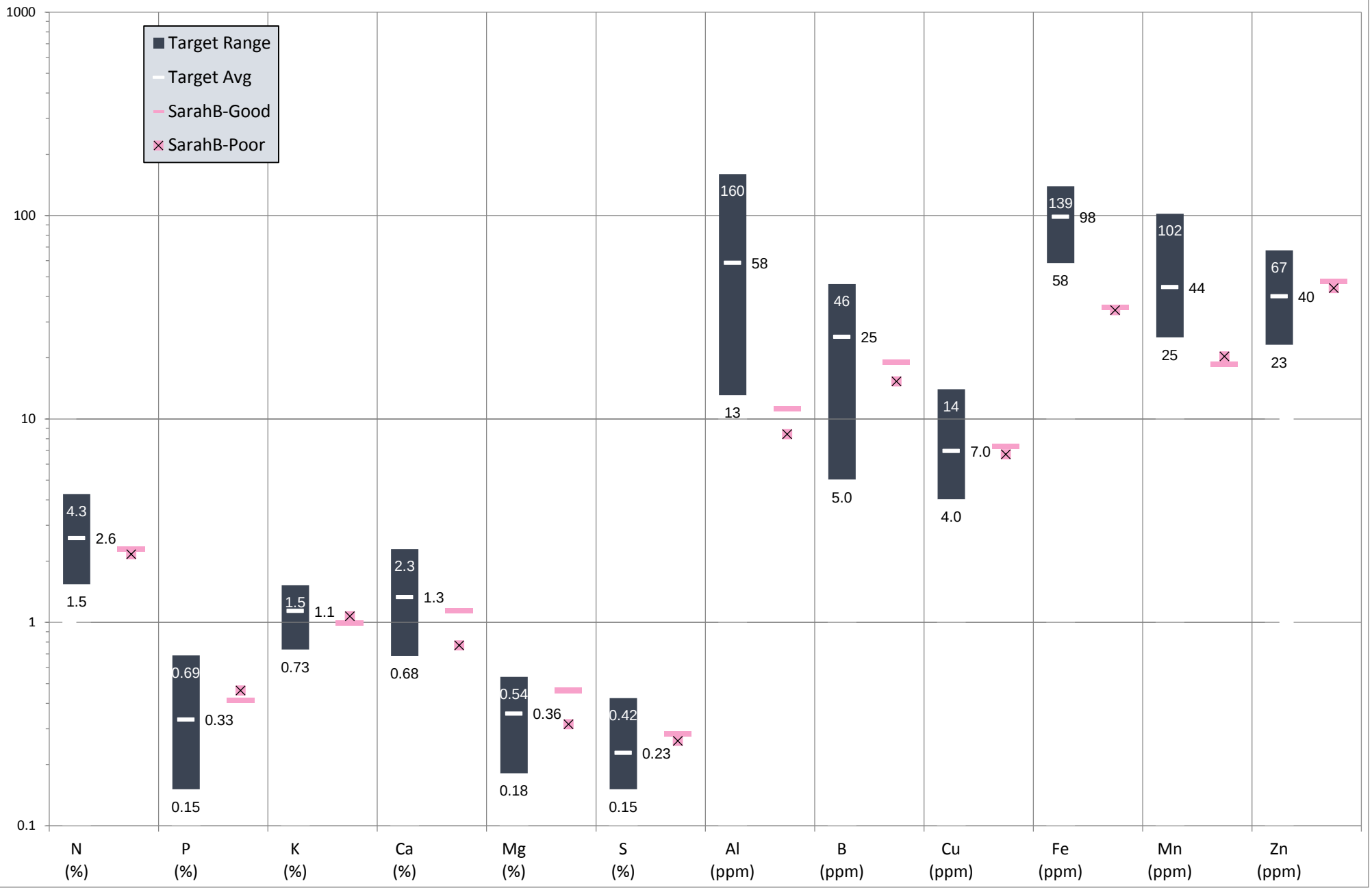
**Grower 7**




2014 Tissue Data Compared to Target Ranges
Grower 9
Target Range
Target Avg
Duchess-Good
Duchess-Poor
SarahB-Good
SarahB-Poor
1000
100
10
1
0.1
4.3
2.6
1.5
0.69
0.33
0.15
1.5
1.1
0.73
2.3
1.3
0.68
0.54
0.36
0.18
0.42
0.23
0.15
160
58
13
46
25
5.0
14
7.0
4.0
139
98
58
102
44
25
67
40
23
N (%)
P (%)
K (%)
Ca (%)
Mg (%)
S (%)
Al (ppm)
B (ppm)
Cu (ppm)
Fe (ppm)
Mn (ppm)
Zn (ppm)

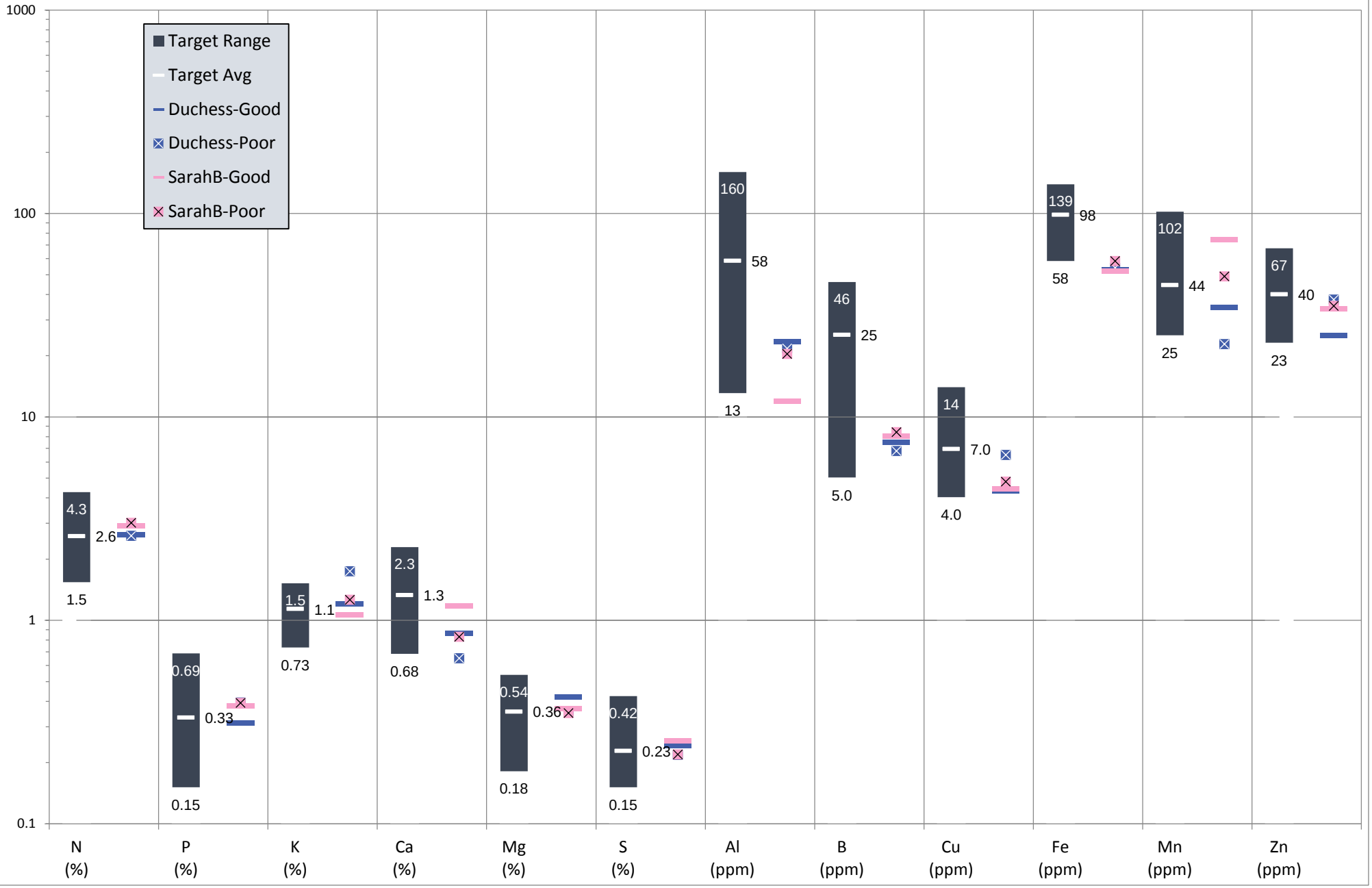
## 2014 Tissue Data Compared to Target Ranges

**Grower 11**



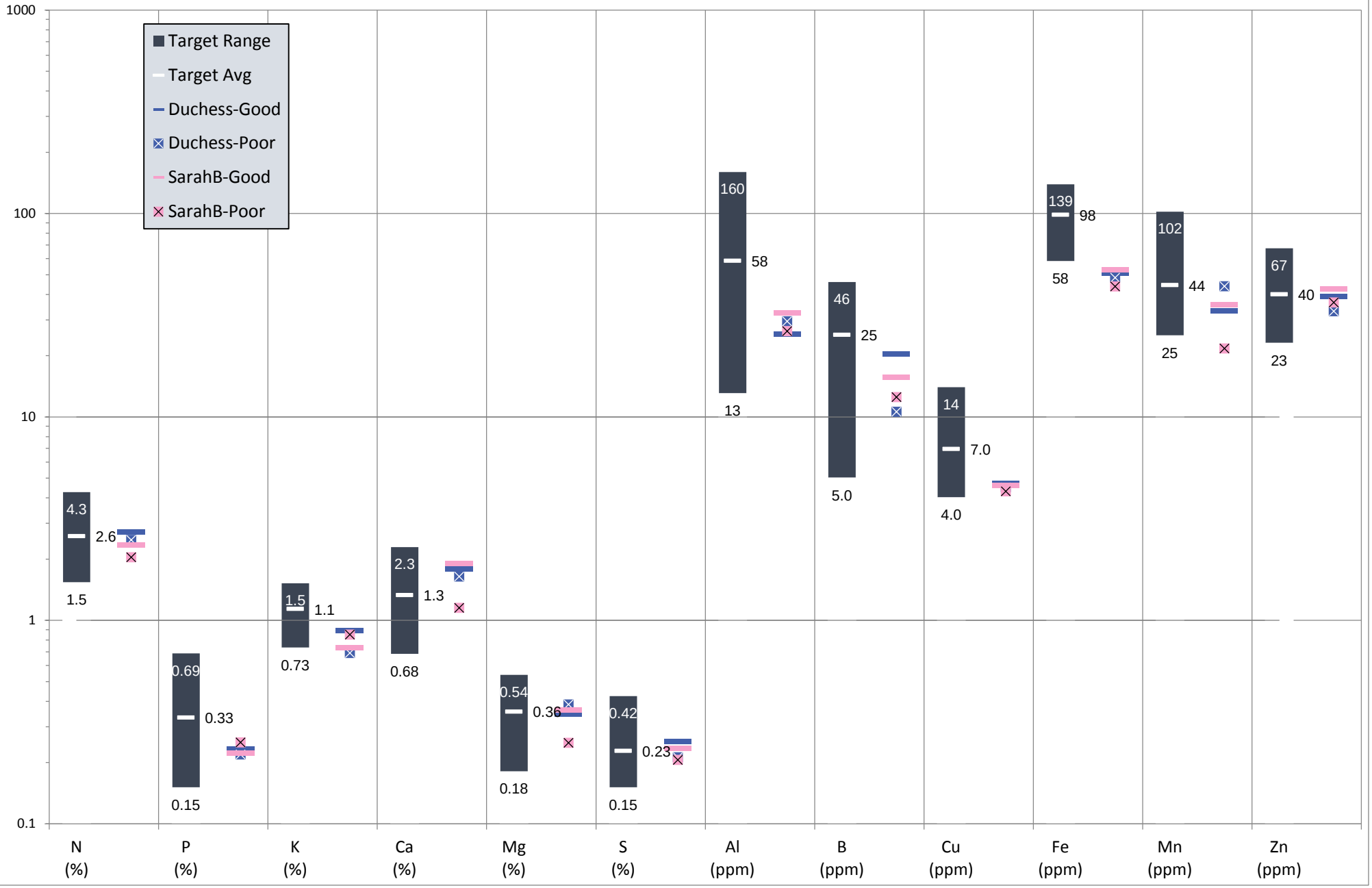
## 2014 Tissue Data Compared to Target Ranges

**Grower 12**



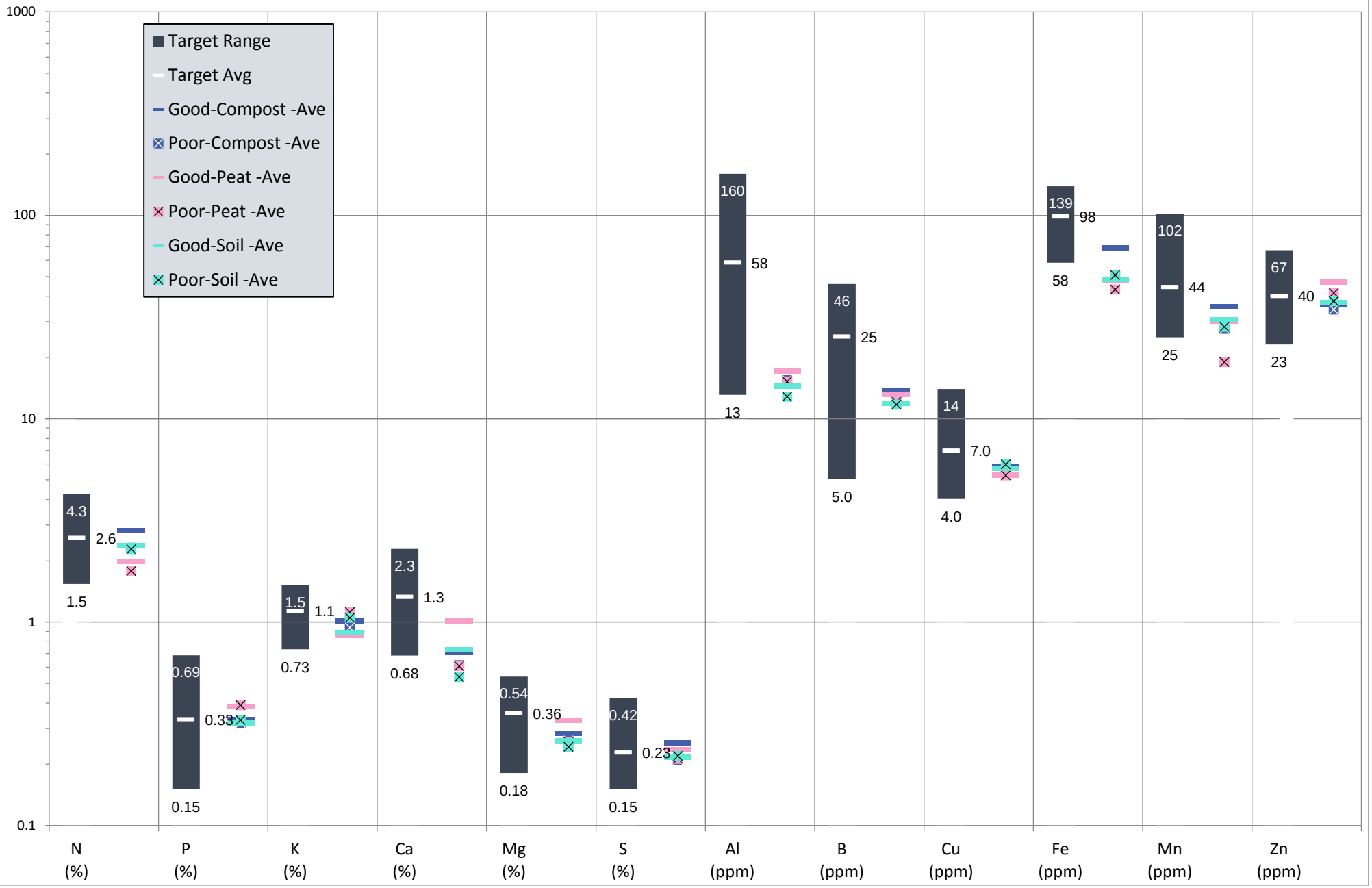
## 2014 Tissue Data Compared to Target Ranges

**Grower 17**



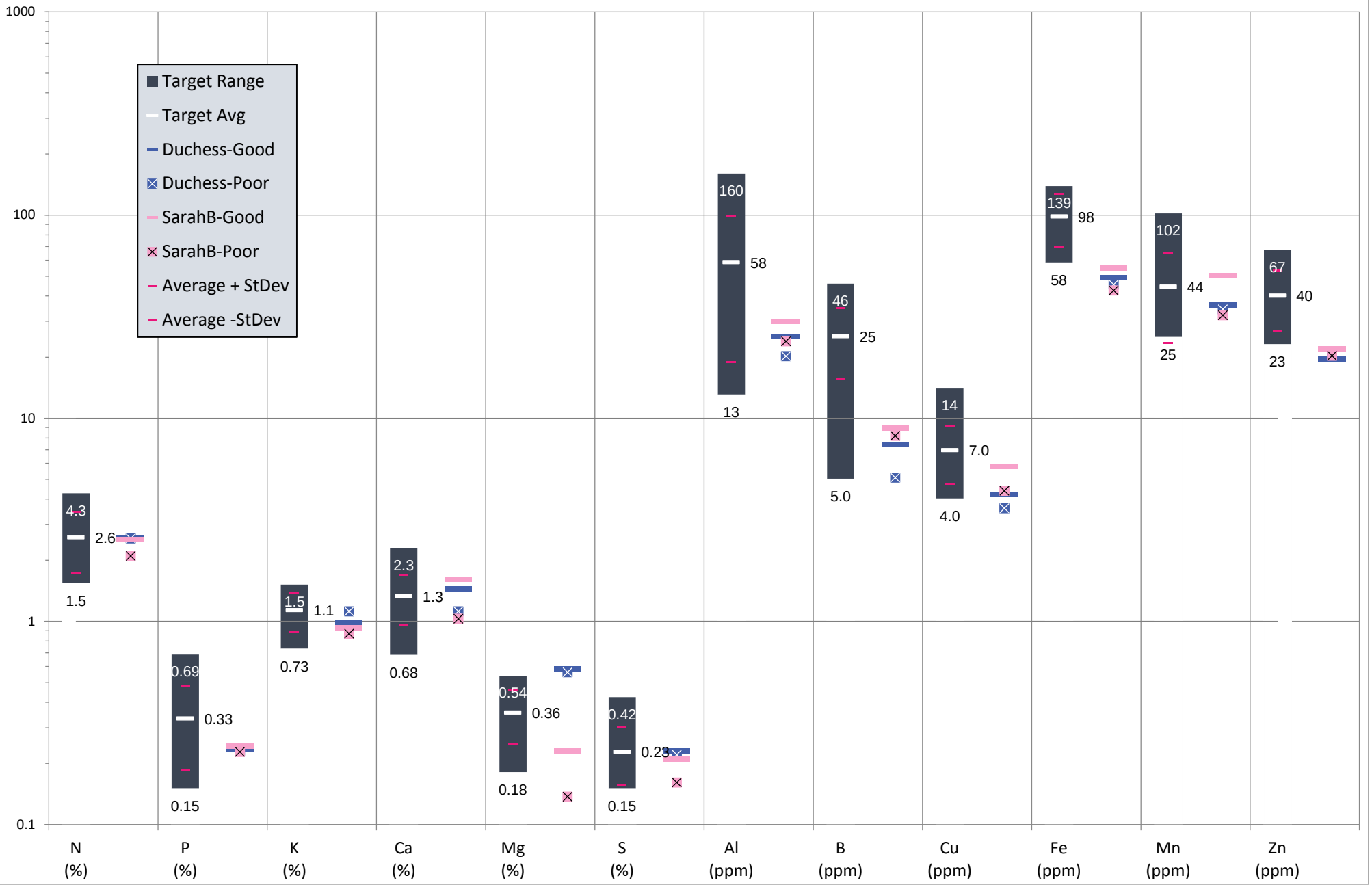
## 2014 Tissue Data Compared to Target Ranges

**Grower 18**



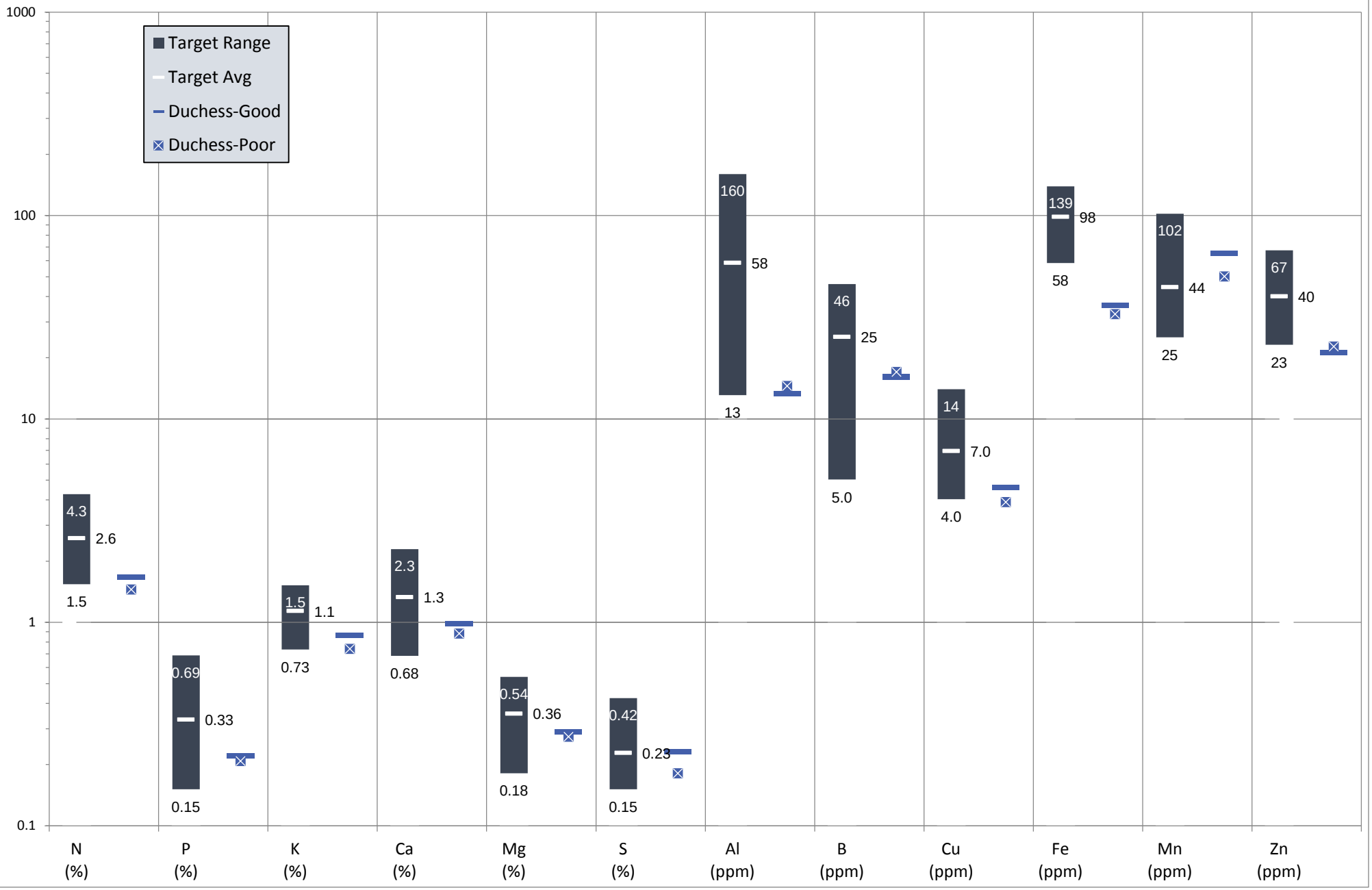
## 2014 Tissue Data Compared to Target Ranges

**Grower 41**



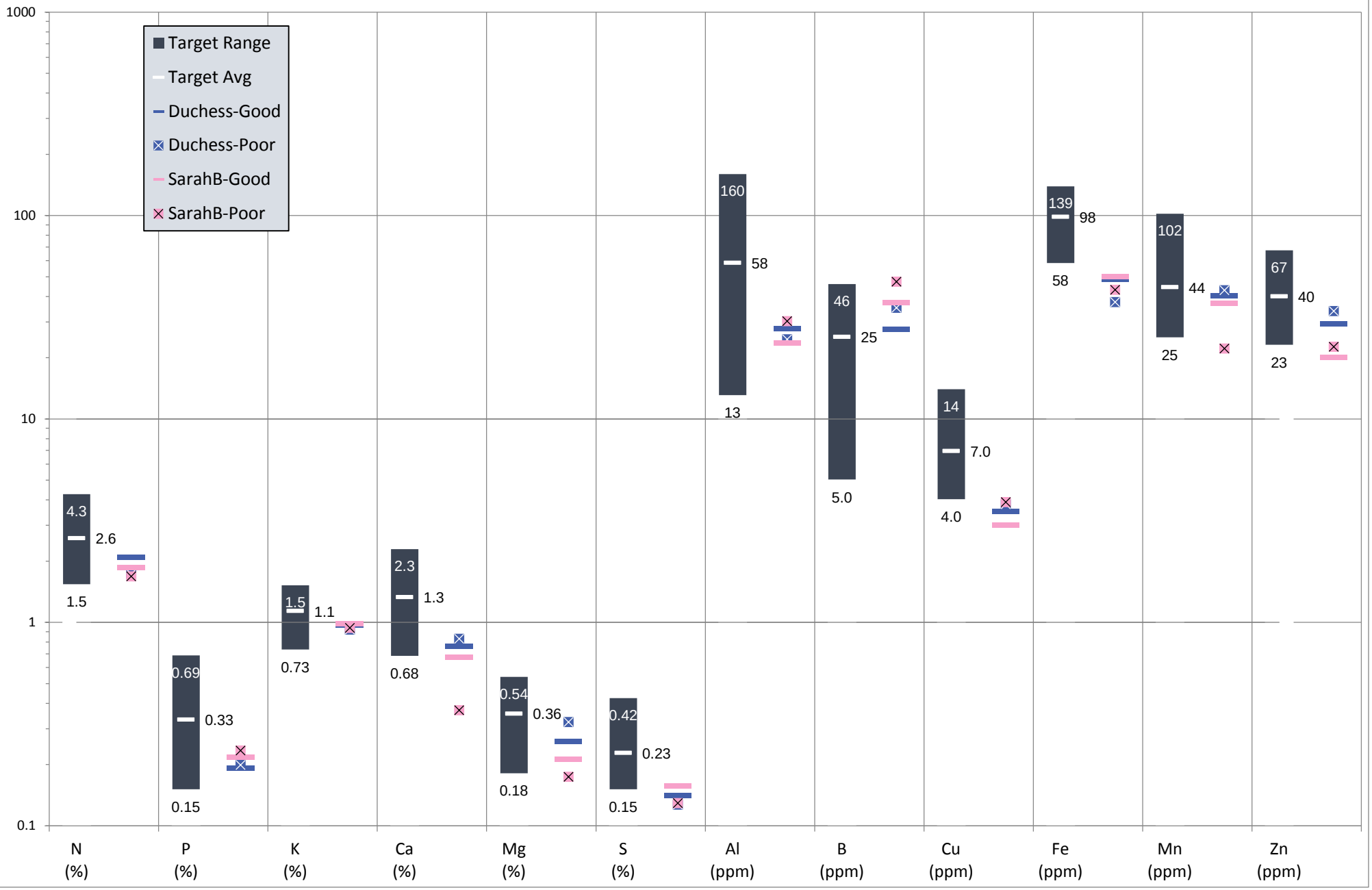
## 2014 Tissue Data Compared to Target Ranges

**Grower 42**



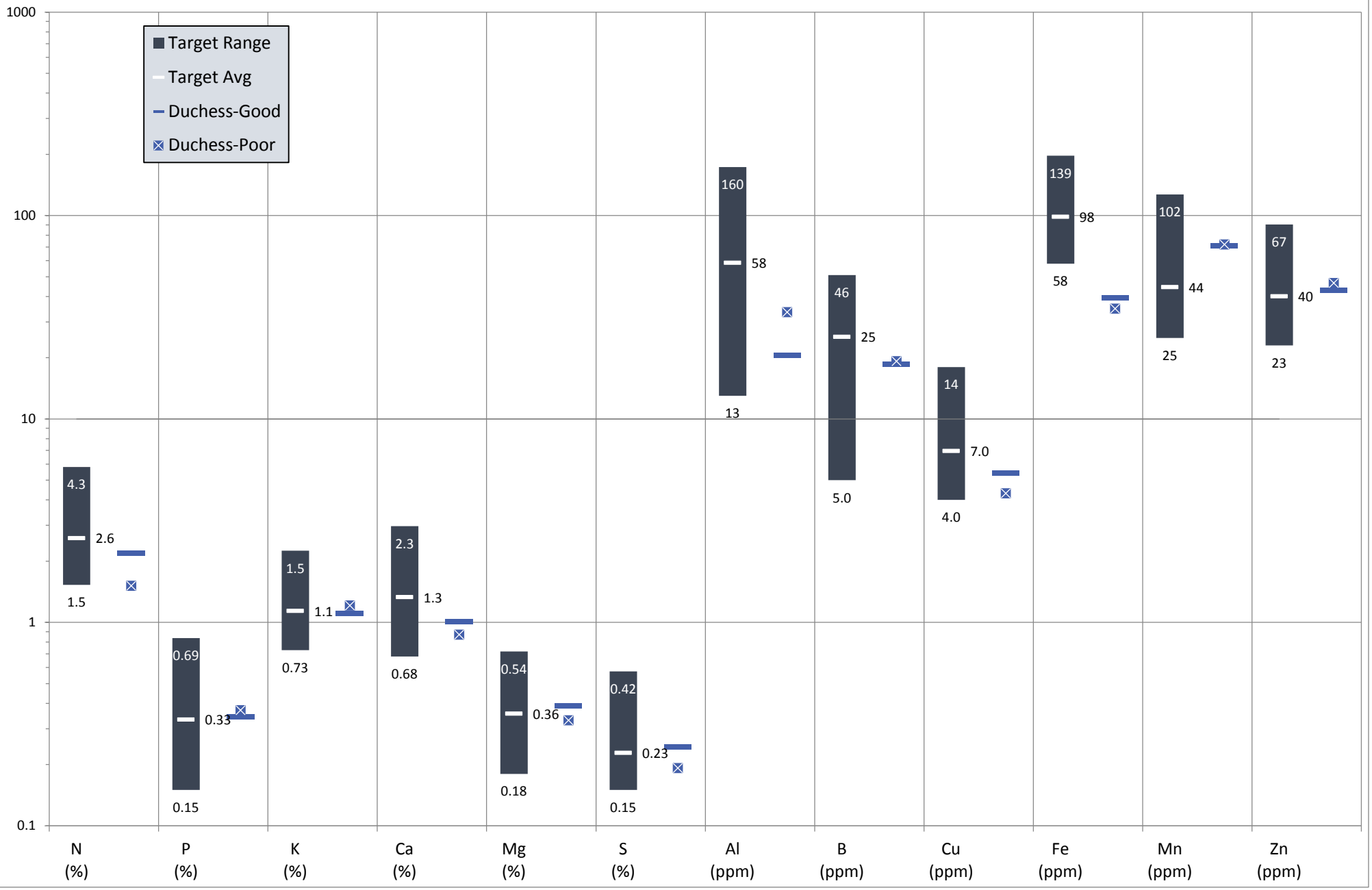
## 2014 Tissue Data Compared to Target Ranges

**Grower 43**



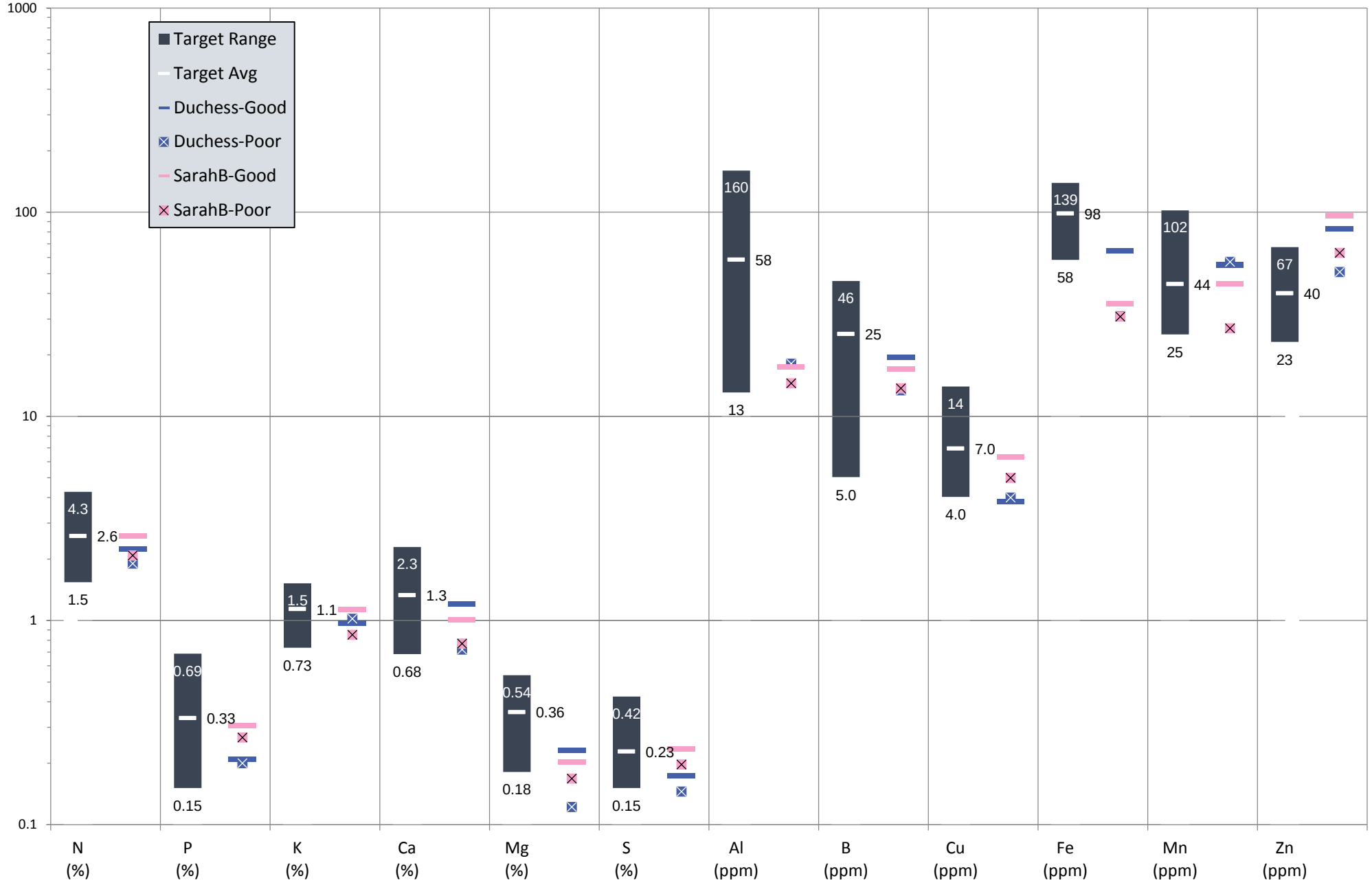
## 2014 Tissue Data Compared to Target Ranges

**Grower 44**



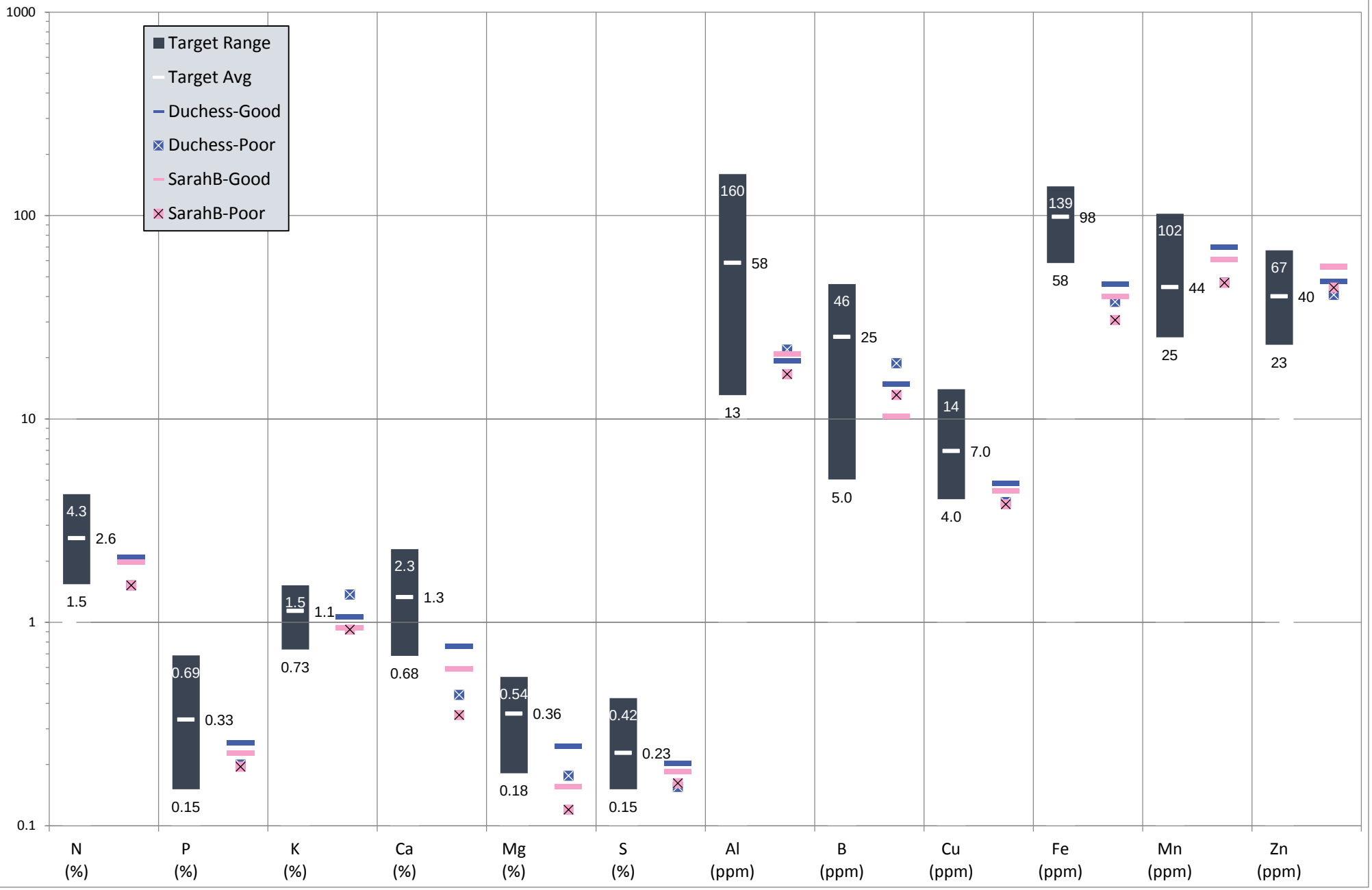
## 2014 Tissue Data Compared to Target Ranges

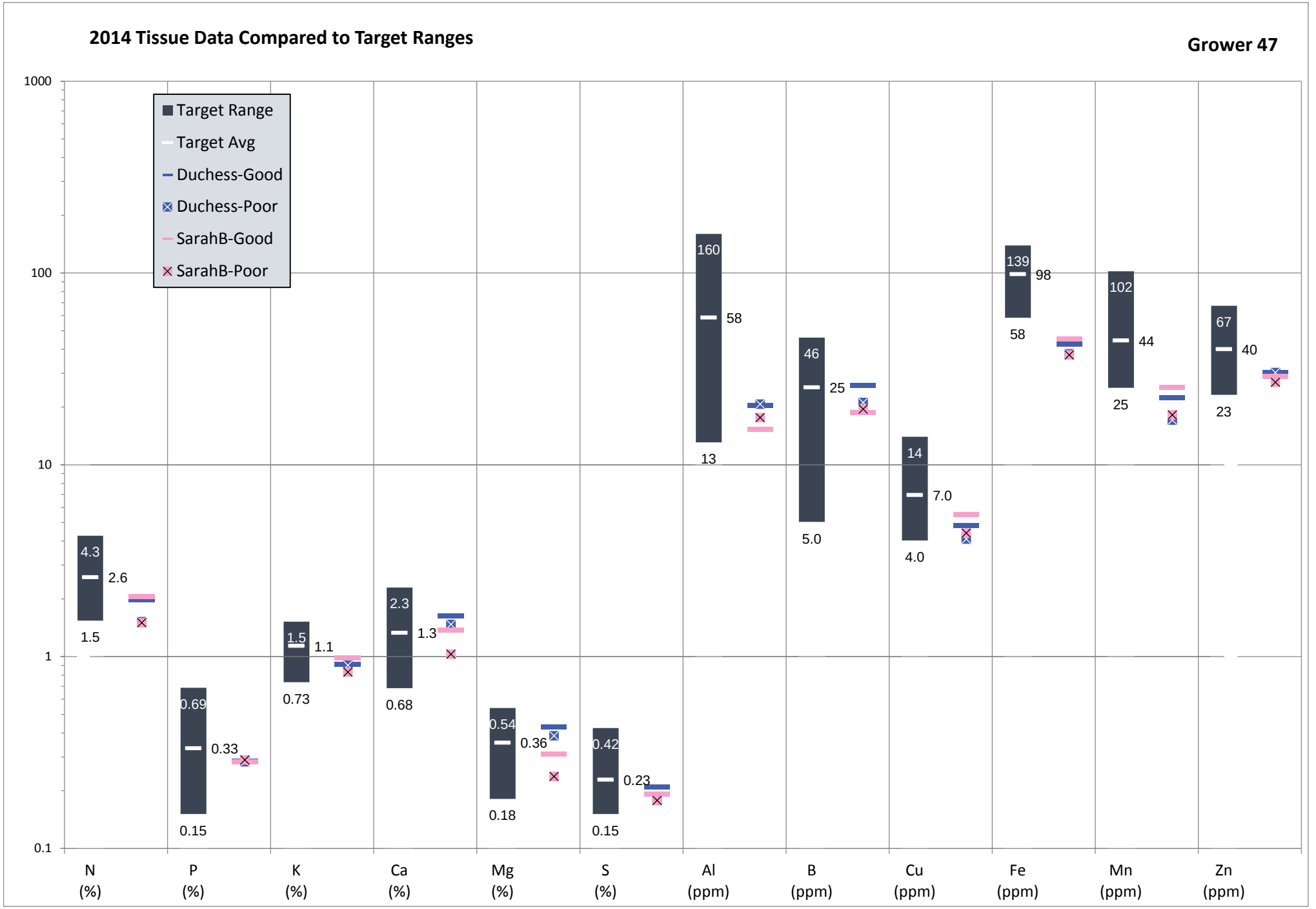
**Grower 45**



## 2014 Tissue Data Compared to Target Ranges

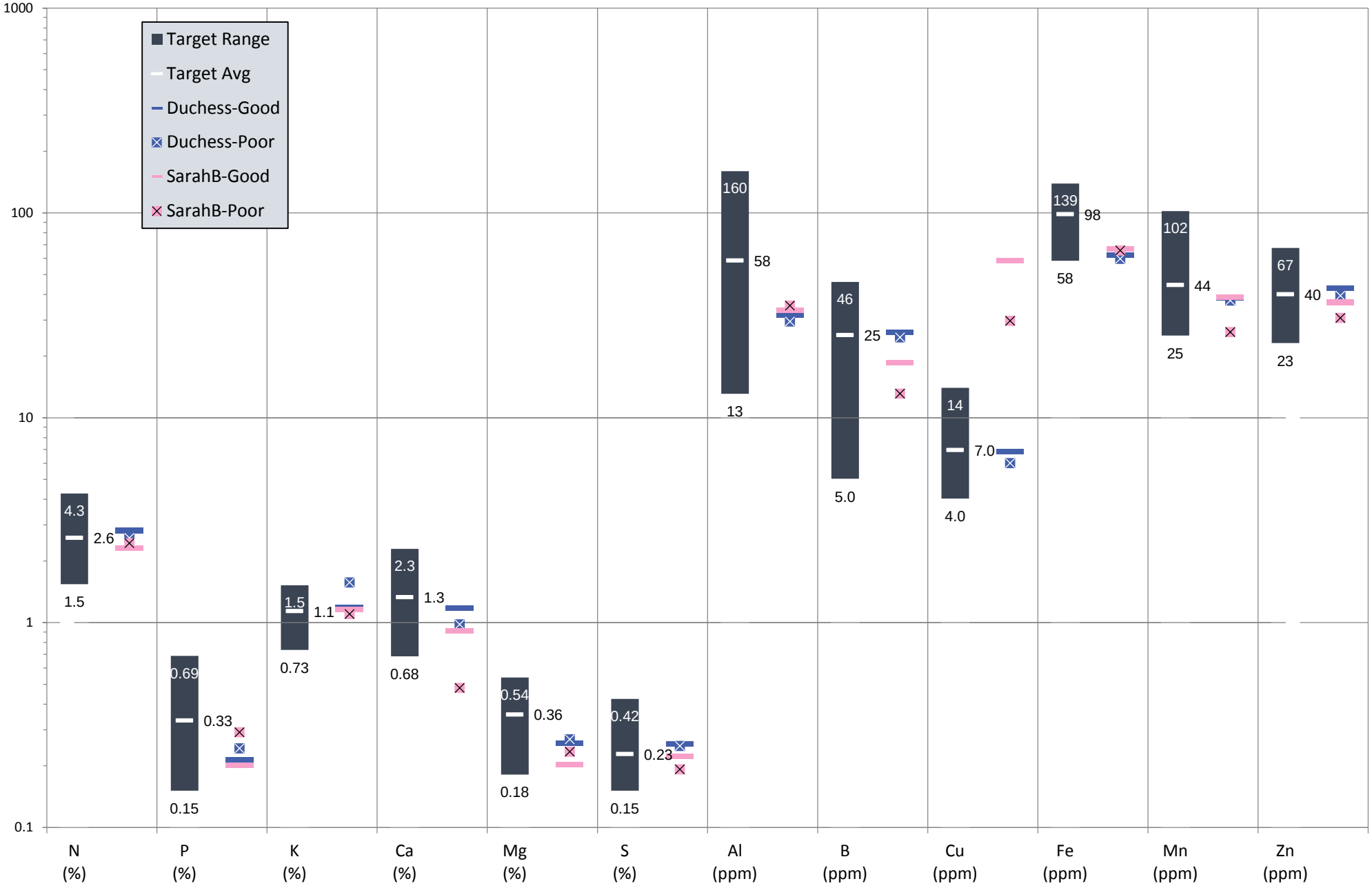
**Grower 46**

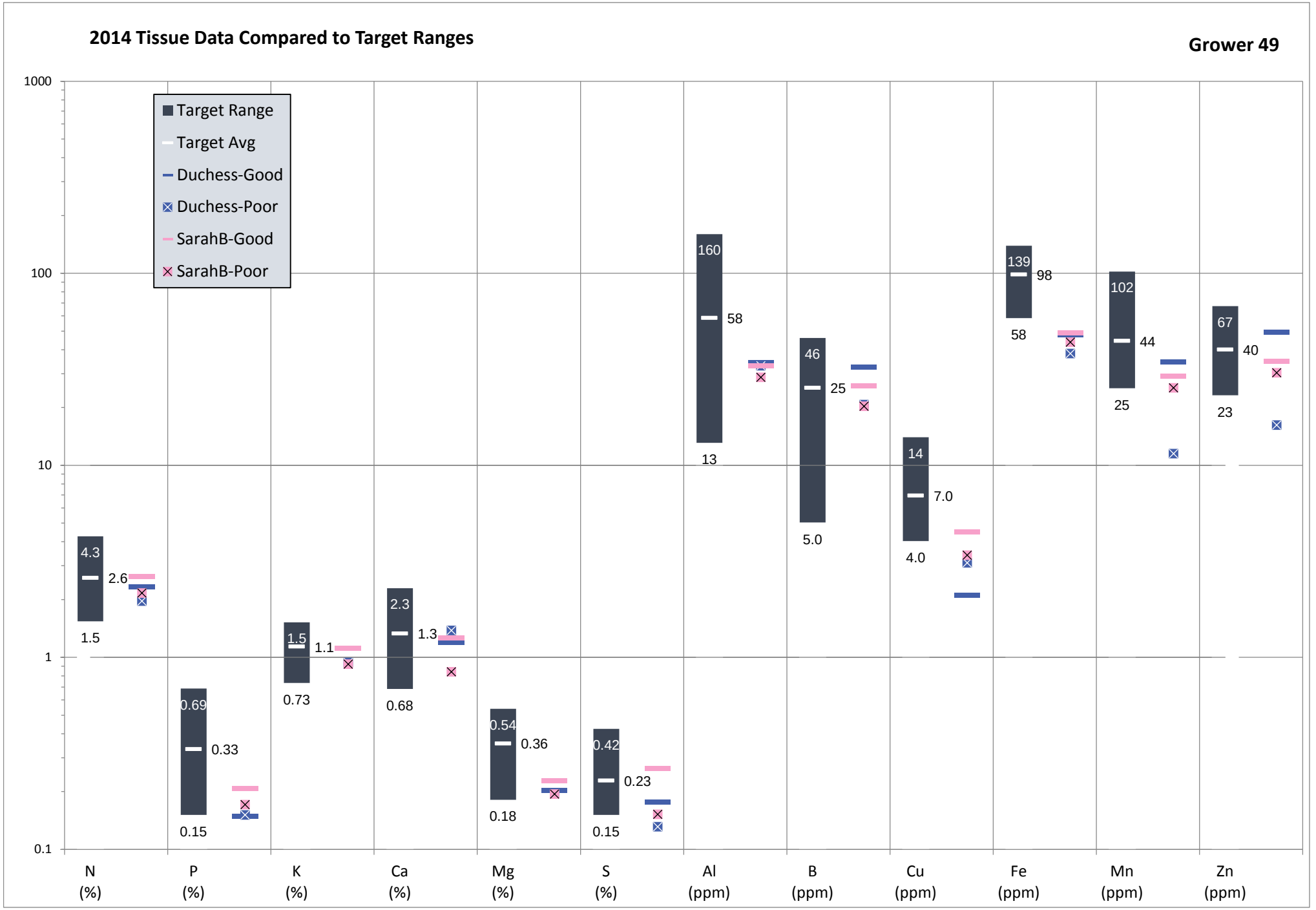



2014 Tissue Data Compared to Target Ranges
Grower 47
Target Range
Target Avg
Duchess-Good
Duchess-Poor
SarahB-Good
SarahB-Poor
1000
100
10
1
0.1
4.3
2.6
1.5
0.69
0.33
0.15
1.5
1.1
0.73
2.3
1.3
0.68
0.54
0.36
0.18
0.42
0.23
0.15
160
58
13
46
25
5.0
14
7.0
4.0
139
98
58
102
44
25
67
40
23
N (%)
P (%)
K (%)
Ca (%)
Mg (%)
S (%)
Al (ppm)
B (ppm)
Cu (ppm)
Fe (ppm)
Mn (ppm)
Zn (ppm)

## 2014 Tissue Data Compared to Target Ranges

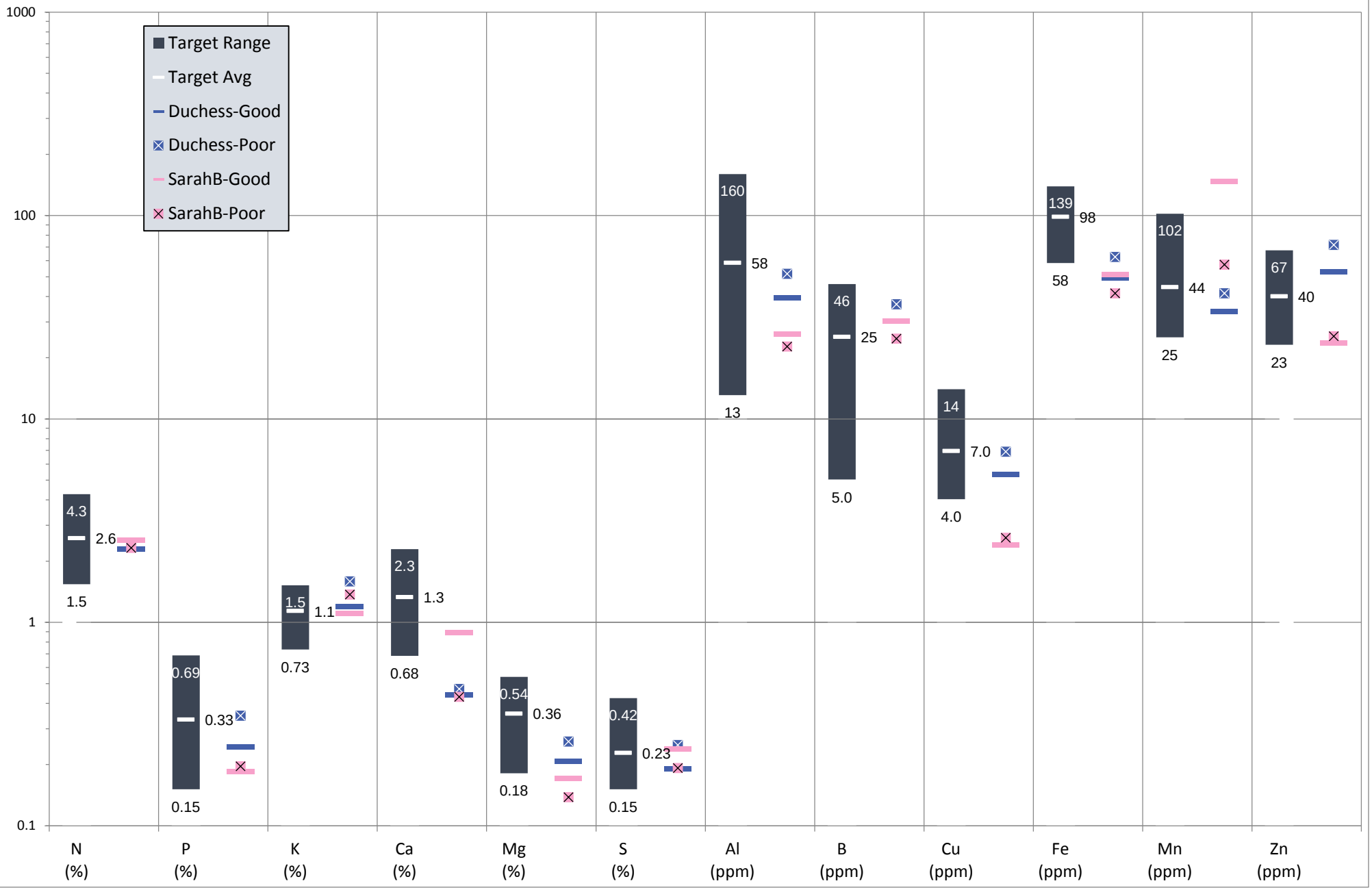
**Grower 48**




2014 Tissue Data Compared to Target Ranges
Grower 49
Target Range
Target Avg
Duchess-Good
Duchess-Poor
SarahB-Good
SarahB-Poor
1000
100
10
1
0.1
4.3
2.6
1.5
0.69
0.33
0.15
1.5
1.1
0.73
2.3
1.3
0.68
0.54
0.36
0.18
0.42
0.23
0.15
160
58
13
46
25
5.0
14
7.0
4.0
139
98
58
102
44
25
67
40
23
N (%)
P (%)
K (%)
Ca (%)
Mg (%)
S (%)
Al (ppm)
B (ppm)
Cu (ppm)
Fe (ppm)
Mn (ppm)
Zn (ppm)

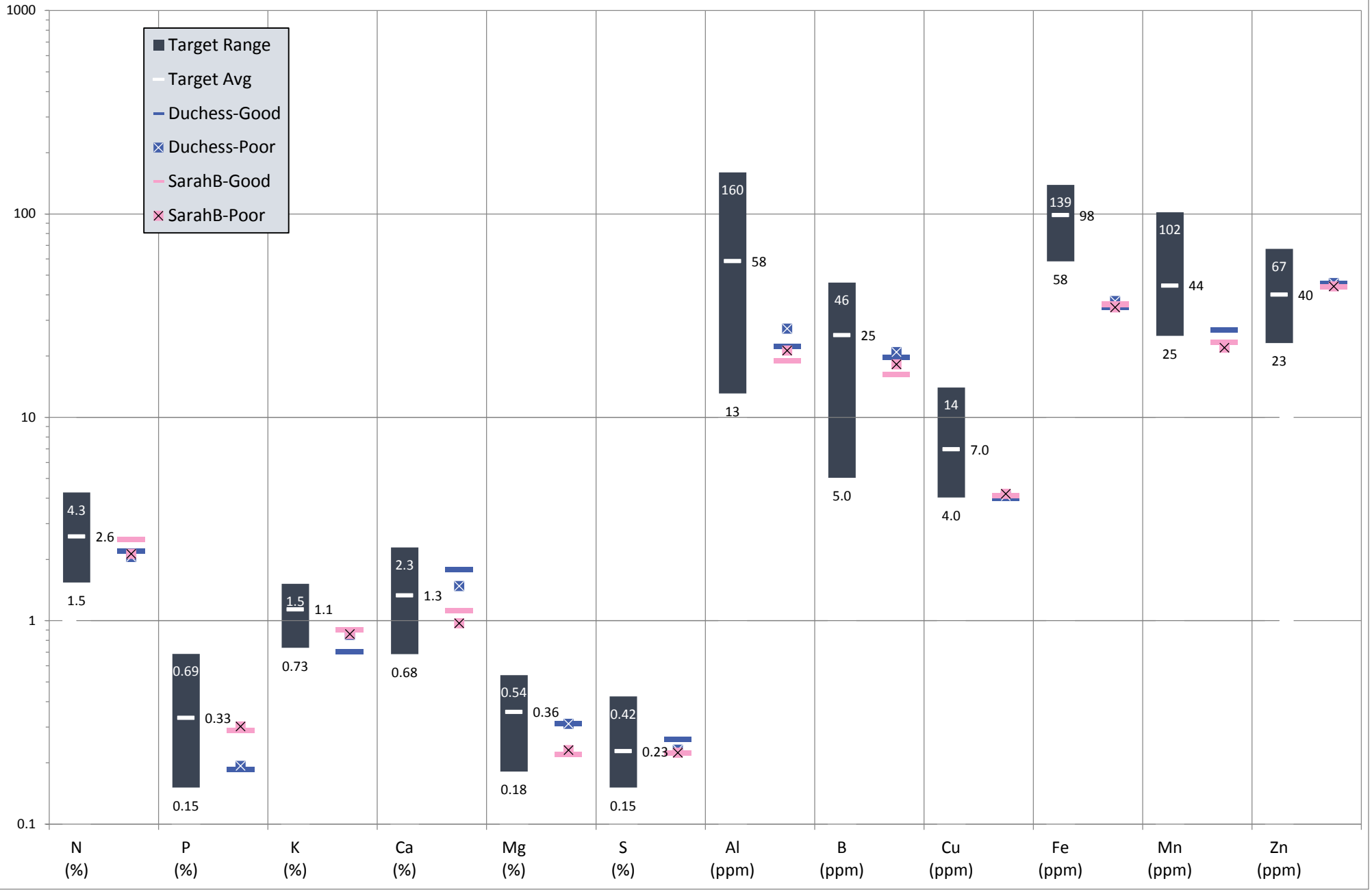
## 2014 Tissue Data Compared to Target Ranges

**Grower 50**



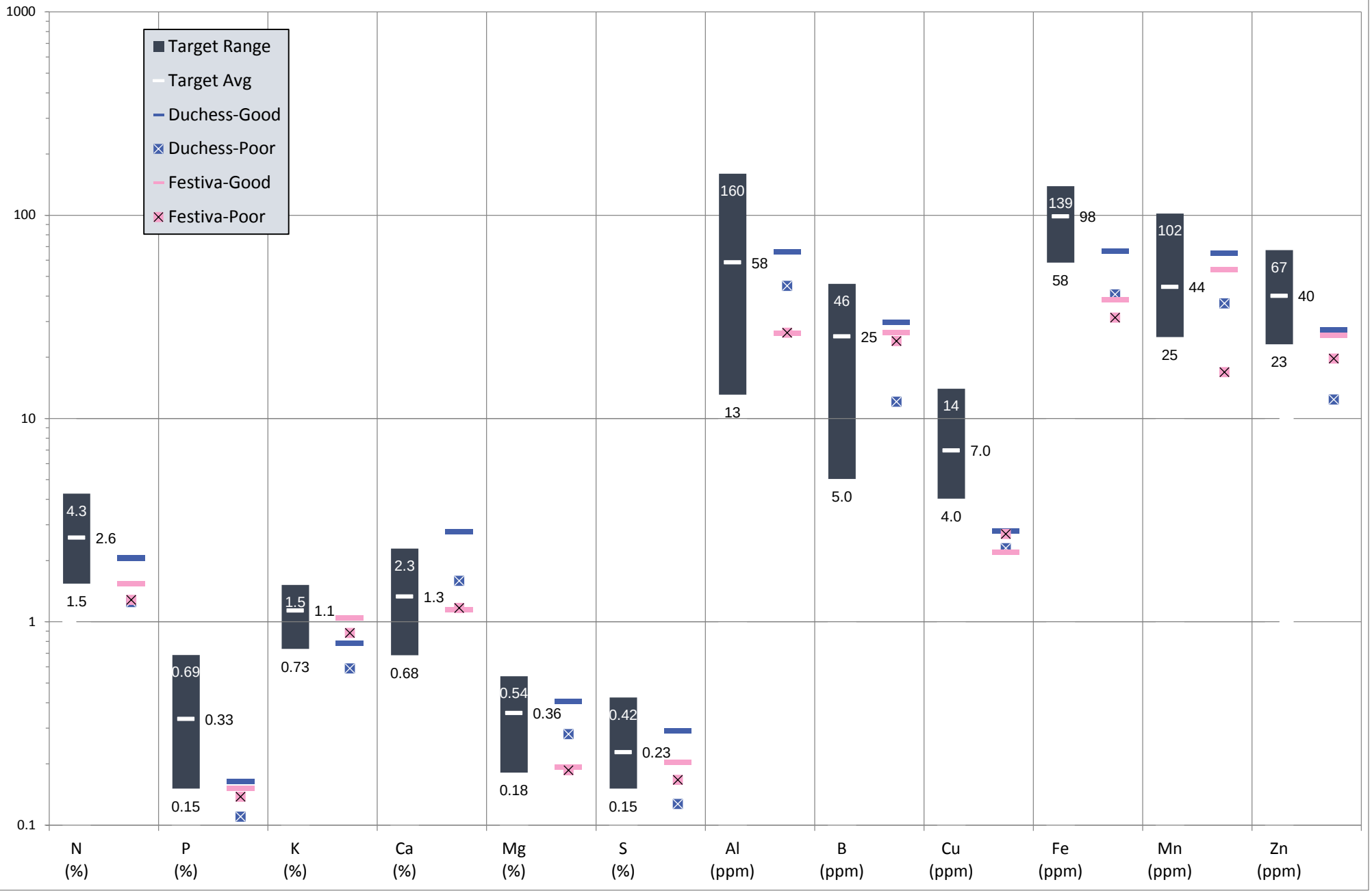
## 2014 Tissue Data Compared to Target Ranges

**Grower 51**



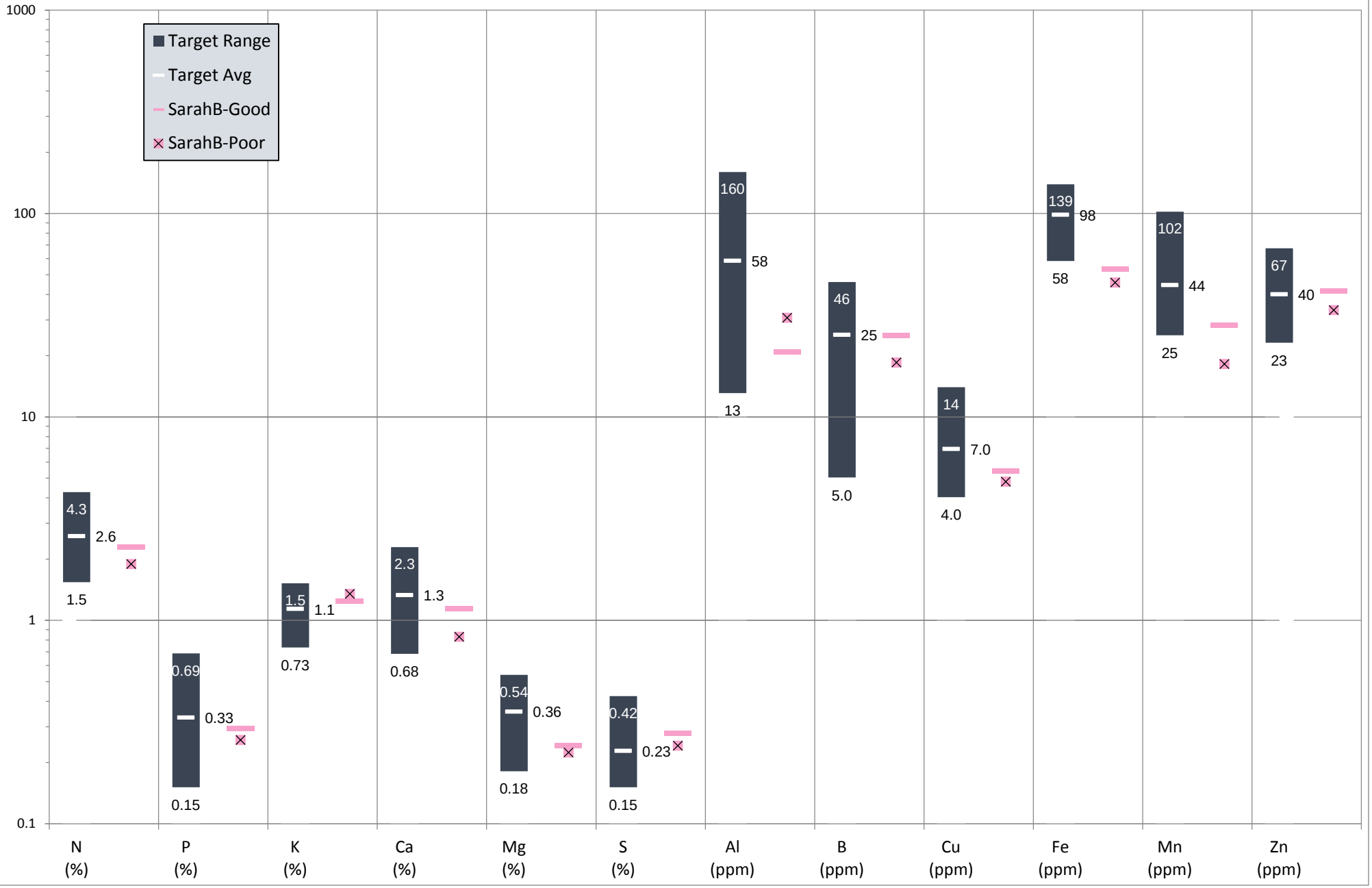
## 2014 Tissue Data Compared to Target Ranges

**Grower 52**



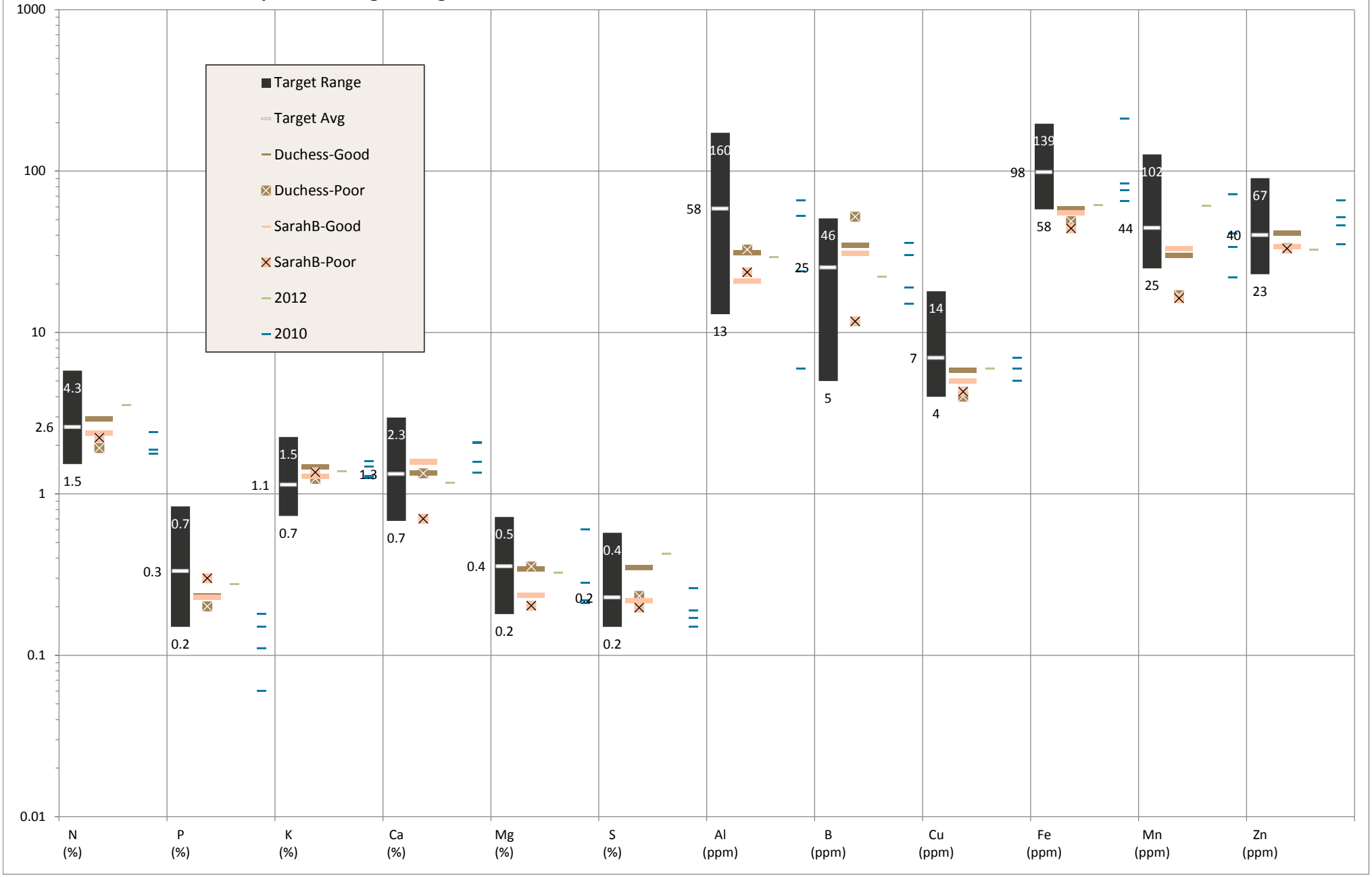
## 2014 Tissue Data Compared to Target Ranges

**Grower 53**



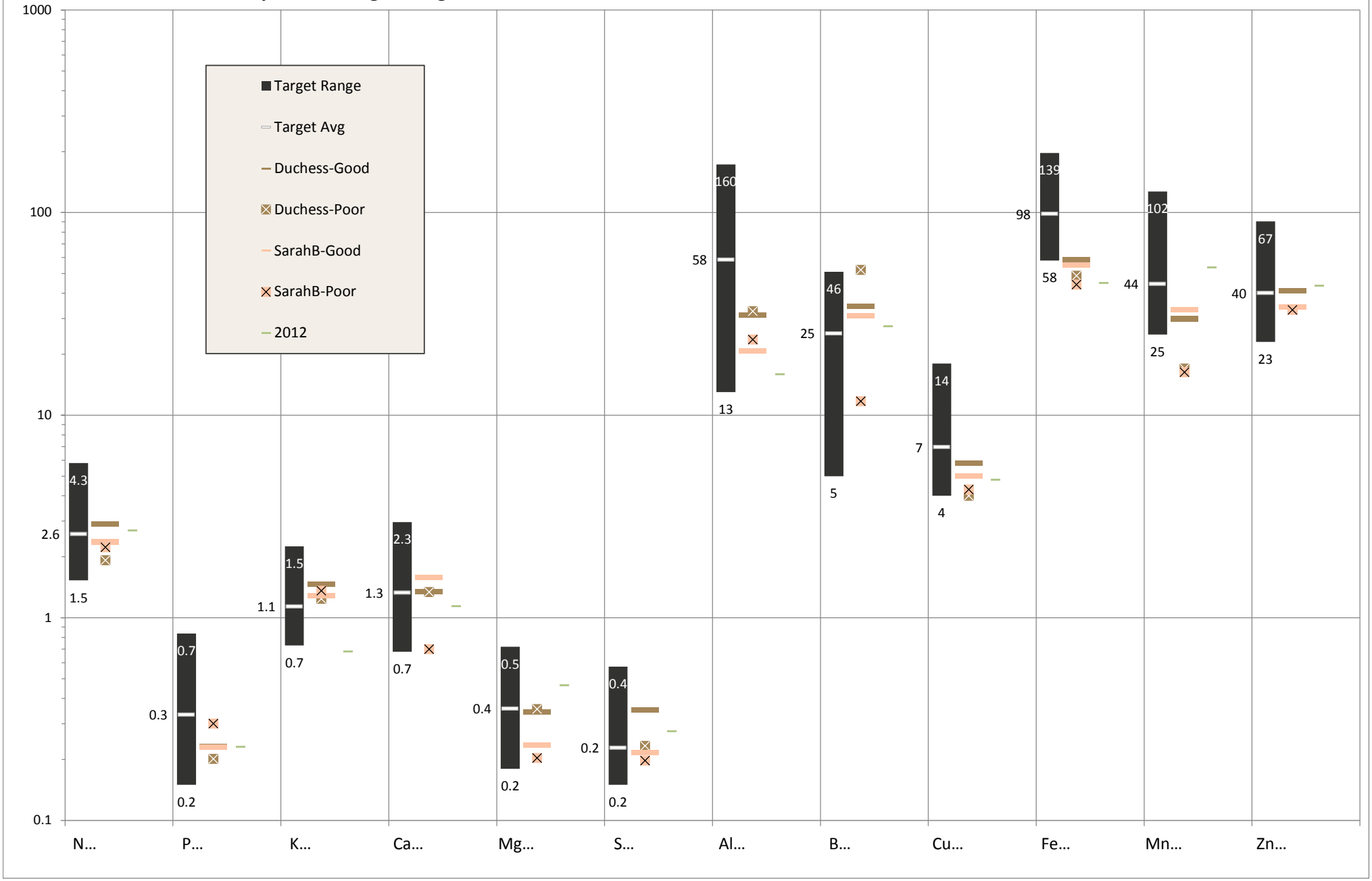
## 2014 Tissue Data Compared to Target Ranges

**Grower 3**



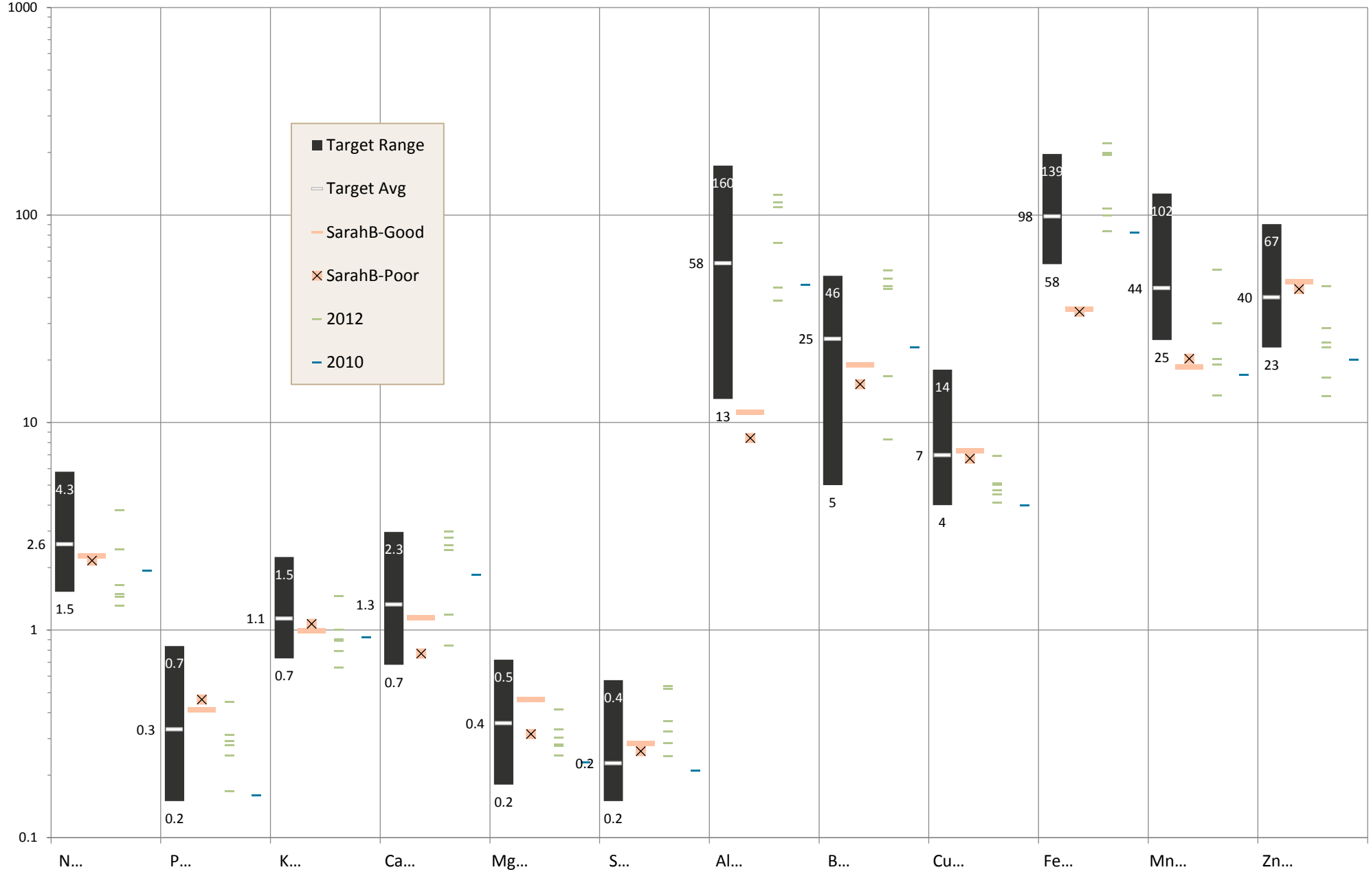
## 2014 Tissue Data Compared to Target Ranges

**Grower 5**



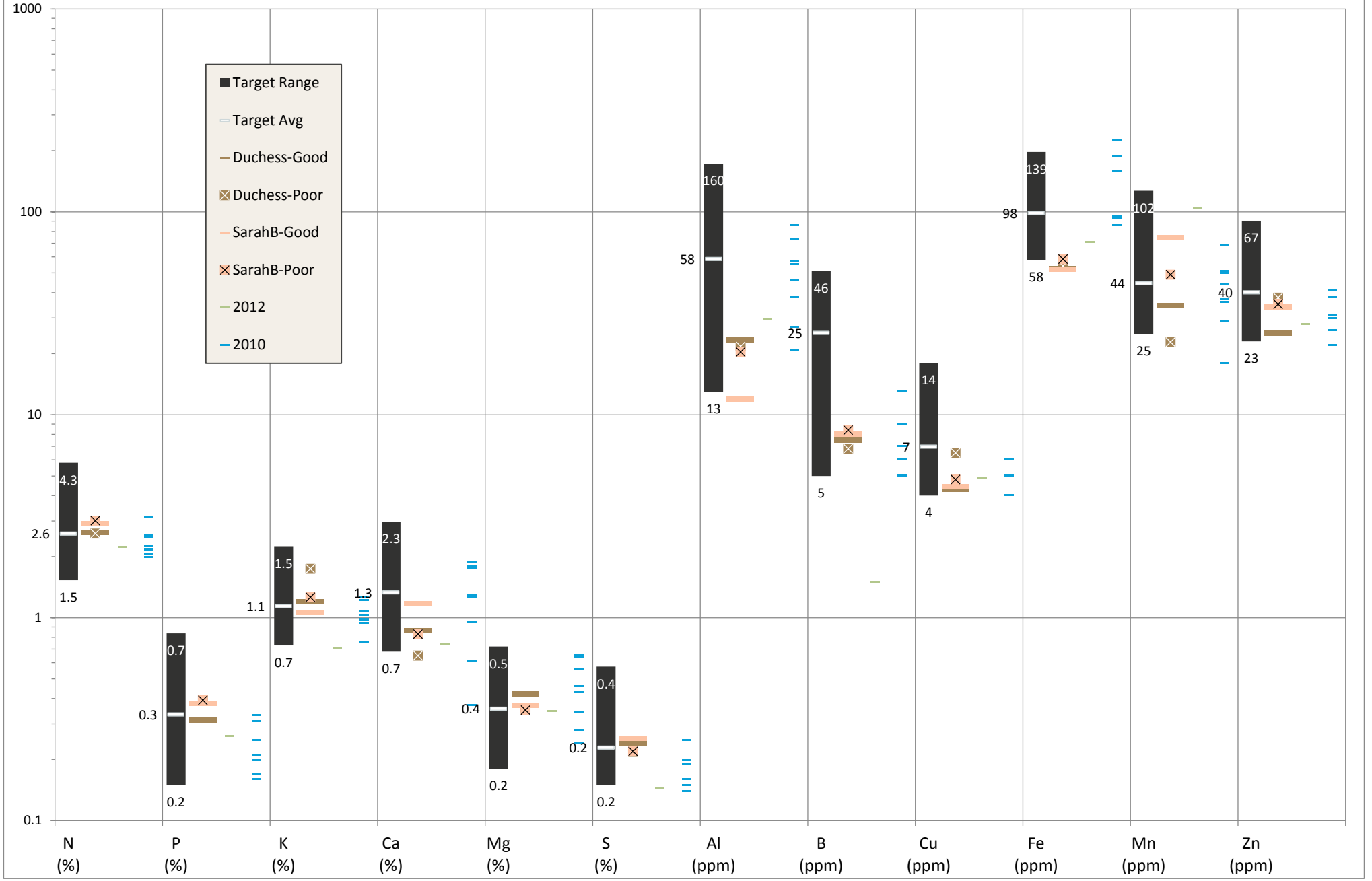
## 2014 Tissue Data Compared to Target Ranges

**Grower 11**



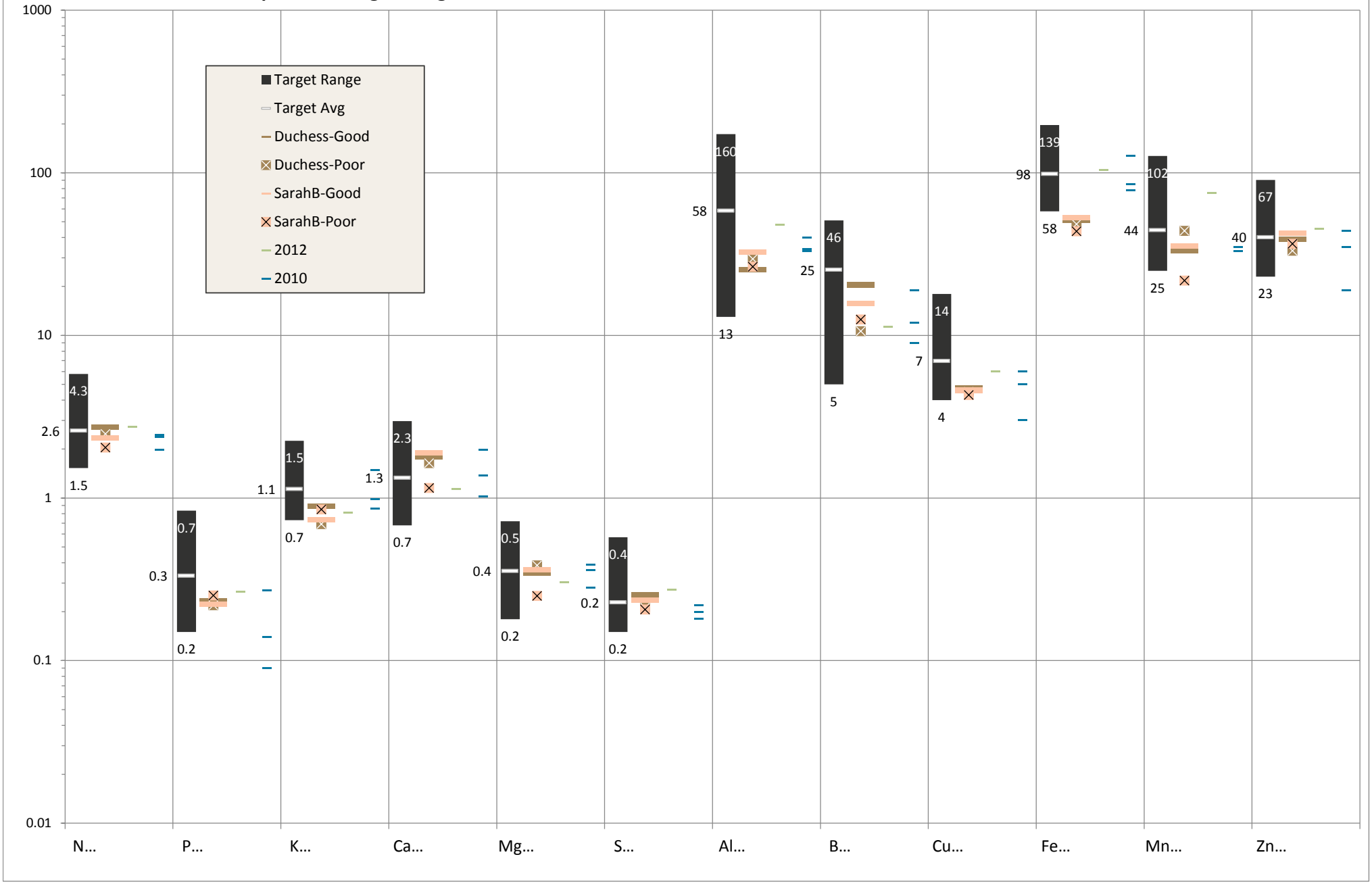
## 2014 Tissue Data Compared to Target Ranges

**Grower 12**



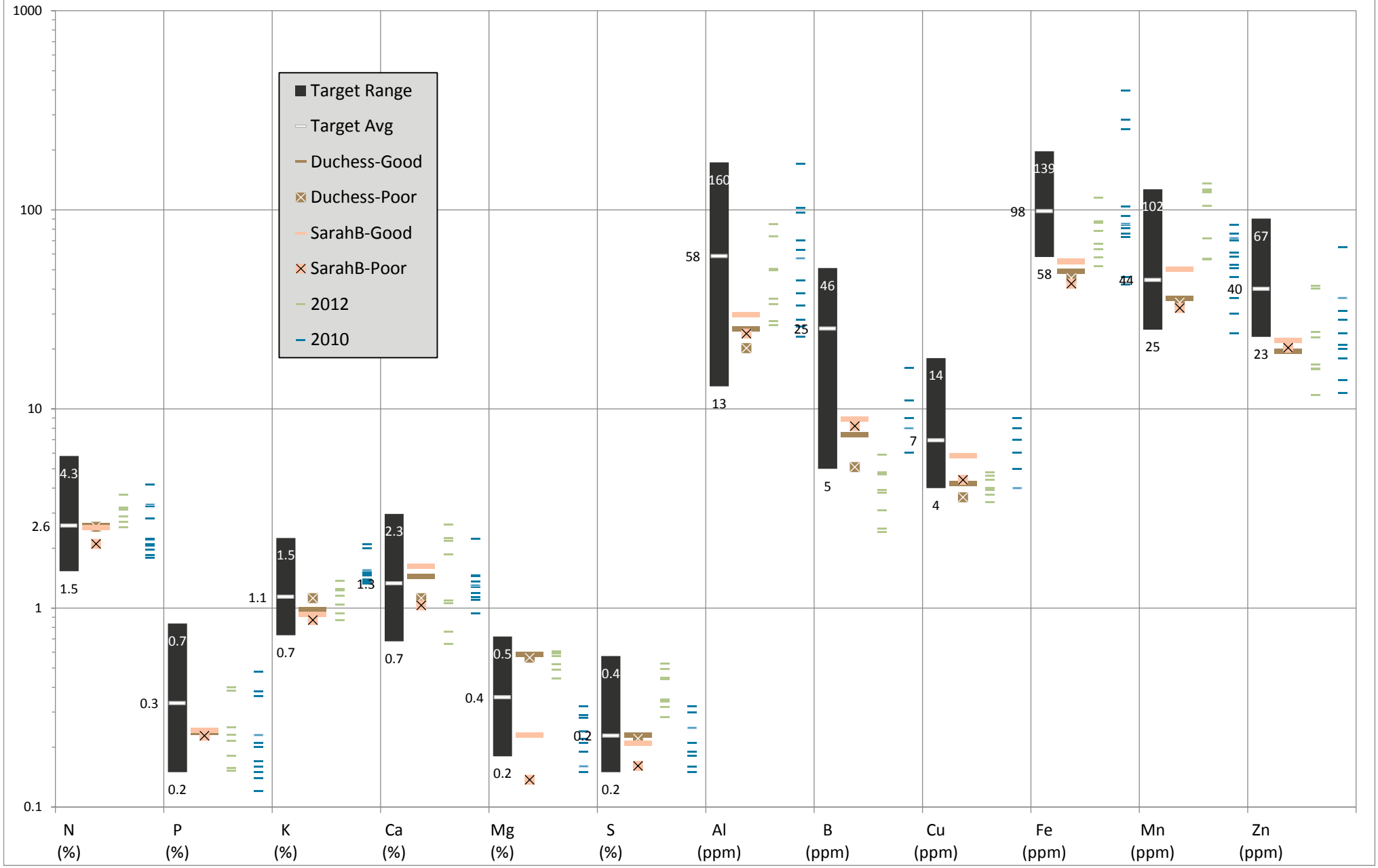
## 2014 Tissue Data Compared to Target Ranges

**Grower 17**



## 2014 Tissue Data Compared to Target Ranges

**Grower 41**



**Summary report for peony nutrient study in Alaska in 2014**

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**Background**

The Alaska peony industry has grown rapidly in recent years. The number of peony growers continues to increase. The industry is pretty new in the state and past soil and nutrient research are mostly for small grains and hay crops. Therefore, there is no current soil or nutrient test standard in the state that can be used to guide growers to apply nutrients to soils for peonies. A study was initiated in 2012 to survey growers' fields for soil and tissue nutrient concentrations. The results of that survey indicated that future survey studies for peonies in the state should include a soil and tissue test for well grown peonies along with a soil and tissue test for poorly grown peonies. Based on this, a diagnostic standard from soil or tissue testing can be established. Therefore, in the summer of 2014, a survey of growers' fields for soil and tissue samples from both well and poorly grown peonies were conducted. The objective of this survey was to determine the range of nutrient concentrations in good and poor peony tissue and soil.

**Approach**

The soil and plant samples were taken from growers' fields prior to flower cutting. Tissue samples were taken randomly from the first leaf from the top, replicated in five plants. The stage for both tissue and soil sampling was at hard bud stage (2.5 maturity index). Soil samples were taken from the depth (0-6 inches or 15 cm) around the peony plant roots. The soil samples were taken from the same peony plants where the tissue samples were taken. There were five soil samples, each of the samples were composited and mixed thoroughly. Samples were taken in three regions: Interior (Fairbanks, Two Rivers, North Pole, and Delta Junction areas), South Central (Trapper Creek, Wasilla, and Palmer areas), and the Kenai Peninsula (Nikiski, Kenai, Soldotna, and Homer areas). The peony cultivars, 'Sarah Bernhardt' and 'Duchess' were used as the standard cultivars for testing because these two cultivars are the most popular in the state. The age of the peony plants at sampling was equal or greater than three-years old, with the exception one or two growers from which two-year old peonies were sampled. Soil samples were air dried, passed through 2-mm sieve, and then placed in a plastic bag

and labeled. Tissue samples were dried at 65°C and then placed in paper bags and labeled. All the samples were sent to Brookside Laboratories Inc. of New Bremen, Ohio for nutrient concentration analysis. In addition to soil and tissue sampling, a survey was also taken from growers regarding fertilization rate, types of fertilizes, and how and when the fertilizers were applied. Upon receiving the analytical results from Brookside Laboratories, the data were analyzed for regional averages.

**Results**

We surveyed 21 growers in the summer of 2014, eight from the interior, four from south central and nine from the Kenai Peninsula. As for types of nutrients the various growers used, there were many different varieties, such as home compost, fish based organic fertilizers, municipal and local compost, peony blend, urea, and triple super phosphate. In essence, growers used a wide variation of both organic and inorganic nutrient sources. Some growers used organic nutrient sources exclusively, whereas others used inorganic sources. Many used a combination of both. For the rate of fertilizer application, it varied greatly from grower to grower. However, the general impression was that most growers over applied nutrients for peonies, especially at the time of planting.

For the basic soil properties of soil organic matter content (SOM), pH, and cation exchange capacity (CEC), the differences between good and poor sites within the same cultivars was narrow. The exception was for the soil organic matter content from the Sarah Bernhardt cultivar in the interior where it was 1% higher in the good site compared to the poor site (Table 1). For all three regions, the

Table 1. Average values (and ranges) of soil organic matter (SOM), pH, cation exchange capacity (CEC) from the interior, south central, and the Kenai Peninsula.

| Analytical item | Sarah Bernhardt | | Duchess | |
|---|---|---|---|---|
| | Good | Poor | Good | Poor |
| Interior | | | | |
| SOM (%) | 7.52 (2.85 – 12.16)[1] | 6.47 (2.84 – 11.20) | 3.83 (2.02 – 5.86) | 3.97 (1.93 – 6.11) |
| pH | 5.8 (4.8 – 7.7) | 5.9 (4.8 – 7.1) | 6.2 (6.1 – 7.5) | 6.2 (5.0 – 7.8) |
| CEC (meq/100g) | 19.51 (9.98 – 23.03) | 17.16 (9.11 – 22.96) | 12.23 (6.13 – 16.39) | 12.19 (7.66 – 17.21) |
| South Central | | | | |
| SOM (%) | 7.48 (3.37 – 11.66) | 7.40 (3.81 – 11.21) | 5.66 (1.75 – 11.01) | 5.51 (2.07 – 10.74) |
| pH | 6.2 (5.3 – 7.2) | 6.1 (5.3 – 7.0) | 6.2 (5.6 – 7.0) | 6.2 (5.6 – 7.1) |
| CEC (meq/100g) | 9.80 (5.42 – 12.58) | 8.92 (5.92 – 11.73) | 8.21 (5.21 – 12.63) | 8.97 (4.76 – 12.64) |
| Kenai Peninsula | | | | |
| SOM (%) | 12.14 (7.85 – 16.07) | 12.78 (9.45 – 15.58) | 12.67 (4.29 – 17.11) | 11.88 (3.31 – 17.54) |
| pH | 6.1 (5.2 – 7.1) | 6.1 (5.2 – 6.9) | 5.7 (5.3 – 6.2) | 5.9 (5.5 – 6.2) |
| CEC (meq/100g) | 15.24 (11.57 – 20.60) | 15.54 (10.33 – 23.40) | 13.44 (9.85 – 22.85) | 13.76 (9.14 – 27.91) |

[1]Numbers in the parenthesis = range of the tested item in the samples.

soil organic matter content and soil CEC were higher from the Sarah Bernhardt cultivar as compared to the Duchess (Table 1). The Sarah Bernhardt cultivar is most likely the first and most popular peony grown in all three regions. As such, the soil from around the Sarah Bernhardt cultivar might have a longer history of cultivation and receiving inputs (i.e. organic sources of nutrients) than the soil around the more newly planted Duchess cultivar. Compared amongst all three regions, soils from the Kenai Peninsula seemed to have higher organic matter content. However, the CEC in the interior for the Sarah Bernhardt cultivar was slightly greater than the ones from the Kenai Peninsula (Table 1). Since both soil organic matter and clay minerals contribute soil CEC, in the interior the ability of the soil to hold nutrients was mainly due to clay minerals, whereas, that ability was mostly due to soil organic matter in the Kenai Peninsula. For both soil organic matter content and CEC, the south central region appeared to be lower than the other two regions (Table 1).

The soil macronutrient concentrations of soil mineral nitrogen (N), Mehlich 3 phosphorus (P), and exchangeable potassium (K) were all higher in the interior from the soils around the Sarah Bernhardt cultivar compared to the other two regions (Table 2). For the Duchess cultivar, that difference was not as pronounced as the Sarah Bernhardt (Table 2). The soil mineral N is the nitrogen in the soil that is in a readily available form for plant nutrient uptake. For example, a value of nearly 50 ppm N from the good site of the Sarah Bernhardt cultivar in the interior, is equal to about 100 lbs N/acre (i.e. 217.4 lbs of urea).

Table 2. Average values (and ranges) of soil mineral N ($NH_4$-N + $NO_3$-N), Mehlich 3 phosphorus, and exchangeable potassium concentration from the interior, south central, and the Kenai Peninsula.

| Analytical item | Sarah Bernhardt | | Duchess | |
|---|---|---|---|---|
| | Good | Poor | Good | Poor |
| Interior | | | | |
| Mineral N (ppm) | 49.9 (6.5 – 88.1) [1] | 36.4 (4.9 – 114.5) | 11.9 (4.5 – 27.7) | 22.5 (5.2 – 79.0) |
| Mehlich 3 P (ppm) | 314 (93 – 506) | 266 (93 – 556) | 113 (68 – 176) | 120 (80 – 148) |
| Exchange K (ppm) | 477 (135 – 927) | 363 (19 – 985) | 173 (60 – 259) | 208 (51 – 313) |
| South Central | | | | |
| Mineral N (ppm) | 7.5 (4.6 – 14.3) | 7.2 (4.2 – 12.2) | 8.3 (5.6 – 13.5) | 11.0 (4.7 – 22.4) |
| Mehlich 3 P (ppm) | 102 (52 – 126) | 92 (59 – 113) | 124 (57 – 234) | 130 (67 – 207) |
| Exchange K (ppm) | 200 (105 – 292) | 191 (119 – 254) | 233 (184 – 332) | 292 (223 – 398) |
| Kenai Peninsula | | | | |
| Mineral N (ppm) | 23.4 (6.3 – 59.8) | 14.2 (6.7 – 25.9) | 23.4 (4.8 – 82.6) | 21.6 (4.6 – 90.1) |
| Mehlich 3 P (ppm) | 93 (21 – 190) | 63 (22 – 171) | 61 (14 – 208) | 65 (8 – 241) |
| Exchange K (ppm) | 197 (81 – 451) | 161 (70 – 429) | 157 (50 – 535) | 153 (54 – 537) |

[1]Numbers in the parenthesis = range of the tested item in the samples.

That is a significant amount of nitrogen in soil, especially at the flower cutting time later in the growing season. For the Duchess cultivar, the poor site in the interior had a higher soil mineral N and exchangeable K level in the soil, indicating that the impediment for growth was not from nutrients but some other variable such as weed management (Table 2). The difference among all three regions for the Duchess cultivar was not that obvious as compared to the Sarah Bernhardt cultivar (Table 2).

The difference between good and poor sites of the micronutrient concentrations in the soil, was narrow for both the Sarah Bernhardt and Duchess cultivars (Table 3). However, compared among regions, the calcium (Ca) concentration in soil in the interior was a couple hundred parts per million higher than the one in south central (Table 3). Even though both concentrations were high with no deficiency of Ca, the difference might be attributed to the parent geological materials from which soil was formed and also to the management practice such as use of organic sources of nutrients (bone meal, compost, etc.). Also, higher Ca concentration was observed in the Sarah Bernhardt cultivar as compared to the Duchess. As suggested earlier, the Sarah Bernhardt cultivar might have received more

Table 3. Average values (and ranges) of key soil micronutrient concentrations from the interior, south central and the Kenai Peninsula.

| Analytical item | Sarah Bernhardt | | Duchess | |
|---|---|---|---|---|
| | Good | Poor | Good | Poor |
| Interior | | | | |
| Ca (ppm) | 2035 (637 – 3155) [1] | 1838 (596 – 2277) | 1581 (774 – 2513) | 1530 (460 – 2255) |
| Mg (ppm) | 326 (47 – 668) | 319 (46 – 450) | 228 (61 – 439) | 238 (69 – 497) |
| Zn (ppm) | 10.71 (1.50 – 29.39) | 9.44 (1.52 – 18.44) | 4.82 (2.45 – 7.88) | 5.52 (1.88 – 11.09) |
| Cu (ppm) | 2.43 (1.41 – 5.63) | 2.58 (1.23 – 6.07) | 2.30 (1.21 – 3.64) | 2.36 (1.22 – 3.12) |
| B (ppm) | 0.67 (0.25 – 1.24) | 0.66 (0.30 – 1.16) | 0.46 (0.20 – 0.65) | 0.60 (0.23 – 1.30) |
| Mn (ppm) | 26 (5 – 44) | 25 (4 – 52) | 18 (5 – 44) | 22 (5 – 51) |
| South Central | | | | |
| Ca (ppm) | 1367 (496 – 1984) | 1216 (533 – 1859) | 1128 (662 – 1949) | 1190 (450 – 1898) |
| Mg (ppm) | 112 (41 – 205) | 97 (32 – 200) | 110 (47 – 224) | 118 (47 – 234) |
| Zn (ppm) | 5.68 (2.48 – 10.61) | 7.83 (2.61 – 20.61) | 6.63 (4.51 – 9.24) | 6.38 (3.63 – 10.62) |
| Cu (ppm) | 2.15 (1.35 – 4.13) | 2.33 (1.37 – 4.87) | 2.51 (1.38 – 3.81) | 2.52 (1.49 – 4.37) |
| B (ppm) | 0.48 (0.21 – 0.64) | 0.52 (0.31 – 0.77) | 0.54 (0.46 – 0.61) | 0.66 (0.47 – 0.79) |
| Mn (ppm) | 15 (9 – 18) | 15 (9 – 18) | 20 (17 – 28) | 19 (18 – 19) |
| Kenai Peninsula | | | | |
| Ca (ppm) | 2148 (1610 – 2934) | 2249 (1418 – 3906) | 1688 (1216 – 2696) | 1862 (1152 – 3746) |
| Mg (ppm) | 178 (49 – 643) | 166 (42 – 683) | 137 (60 – 287) | 135 (60 – 271) |
| Zn (ppm) | 4.64 ( 0.74 – 11.23) | 3.84 (1.03 – 4.16) | 3.44 (1.36 – 5.76) | 3.01 (1.03 – 4.63) |
| Cu (ppm) | 1.89 (0.99 – 4.61) | 1.66 (0.89 – 4.79) | 1.35 (0.82 – 2.40) | 1.43 (0.81 – 2.89) |
| B (ppm) | 0.45 (0.22 – 0.84) | 0.36 (0.20 – 0.64) | 0.35 (0.20 – 0.88) | 0.36 (0.20 – 0.91) |
| Mn (ppm) | 14 (6 – 32) | 10 (3 – 15) | 10 (5 – 18) | 8 (2 – 15) |

[1]Numbers in the parenthesis = range of the tested item in the samples.

nutrients over time as compared to the Duchess cultivar due to having a longer history of production. Calcium concentration in the soils from Kenai Peninsula was in the same range as the interior. However, the magnesium (Mg) concentration in the peninsula was apparently lower than the interior (Table 3). Little difference was found among the three regions for copper (Cu) and boron (B). But the zinc (Zn) was apparently higher for the Sarah Bernhardt cultivar in the interior than the in the other two regions, and manganese (Mn) was higher in both the Sarah Bernhardt and Duchess cultivars for the interior compared to the other two regions (Table 3). During the survey, we have not seen any deficiencies for these micronutrients. The variation here served as a status quo of micronutrient concentrations for peonies grown in soils in each of the three regions.

The nutrient concentrations in peony tissue, especially for nitrogen, demonstrated a fairly even range for both good and poor sites for both the Sarah Bernhardt and Duchess cultivars (Table 4). For example, in south central, the good site had a tissue N concentration of 2.23% for the Sarah Bernhardt cultivar, and 2.10% for the Duchess cultivar. In contrast, the poor site only had a nitrogen concentration of 1.75% for the Sarah Bernhardt cultivar and 1.65% for the Duchess cultivar. For the interior and Kenai Peninsula, the difference between good and poor sites in terms of nitrogen concentration was narrow. However, that was most likely due to a higher supply of nutrients from the soil in the interior and Kenai Peninsula (Table 2). For the potassium concentration, it appeared to be negatively related to the nitrogen concentration in peony tissue. That meant a high nitrogen concentration was accompanied by a low potassium concentration in the peony tissue (Table 4). For phosphorus, there was no clear trend (Table 4).

Table 4. Average values (and ranges) of nitrogen, phosphorus, and potassium concentrations in peony tissue from the interior, south central and Kenai Peninsula.

| Analytical item | Sarah Bernhardt | | Duchess | |
|---|---|---|---|---|
| | Good | Poor | Good | Poor |
| Interior | | | | |
| Nitrogen (%) | 2.37 (1.85 – 3.06) [1] | 2.18 (1.68 – 3.01) | 2.35 (1.66 – 2.80) | 2.06 (1.45 – 2.60) |
| Phosphorus (%) | 0.336 (0.201 – 0.411) | 0.347 (0.234 – 0.462) | 0.282 (0.191 – 0.409) | 0.316 (0.199 – 0.480) |
| Potassium (%) | 0.97 (0.83 – 1.16) | 1.06 (0.89 – 1.26) | 1.08 (0.86 – 1.20) | 1.28 (0.74 – 1.74) |
| South Central | | | | |
| Nitrogen (%) | 2.23 (1.98 – 2.58) | 1.75 (1.50 – 2.08) | 2.10 (1.98 – 2.23) | 1.65 (1.52 – 1.90) |
| Phosphorus (%) | 0.277 (0.228 – 0.305) | 0.252 (0.195 – 0.287) | 0.249 (0.209 – 0.285) | 0.228 (0.200 – 0.283) |
| Potassium (%) | 1.07 (0.94 – 1.24) | 0.99 (0.83 – 1.35) | 0.98 (0.91 – 1.06) | 1.10 (0.90 – 1.37) |
| Kenai Peninsula | | | | |
| Nitrogen (%) | 2.37 (1.83 – 2.62) | 2.10 (1.70 – 2.32) | 2.40 (2.06 – 2.90) | 2.03 (1.25 – 2.56) |
| Phosphorus (%) | 0.225 (0.184 – 0.287) | 0.248 (0.171 – 0.302) | 0.214 (0.148 – 0.277) | 0.207 (0.110 – 0.347) |
| Potassium (%) | 0.98 (0.71 – 1.28) | 1.02 (0.85 – 1.37) | 1.00 (0.70 – 1.46) | 0.98 (0.59 – 1.59) |

[1]Numbers in the parenthesis = range of the tested item in the samples.

For the micronutrient concentrations in the peony tissue, a high calcium (Ca) concentration was associated with the good site in all three regions for both cultivars (Table 5). Since calcium can enhance the cell wall strength, the high nitrogen in the peony tissue corresponding with the high calcium concentration was good for plant growth for all growers in all regions. The magnesium (Mg) and boron (B) concentrations also corresponded with the good and poor sites, meaning the good site had higher apparent magnesium and boron concentrations in tissues than did the poor sites (Table 5). For zinc and copper, the gap between the good and poor sites was not as large as for the other micronutrients. However, for the iron (Fe) concentration, there was a large gap between the good and poor sites, especially for the Sarah Bernhardt cultivar (Table 5). Iron is an essential element for chlorophyll production. The high iron concentration in tissue helps the photosynthesis process of the peony plants.

Table 5. Average values (and ranges) of key micronutrient concentrations in peony tissue from the interior, south central and Kenai Peninsula.

| Analytical item | Sarah Bernhardt | | Duchess | |
|---|---|---|---|---|
| | Good | Poor | Good | Poor |
| Interior | | | | |
| Ca (%) | 0.87 (0.66 – 1.17) [1] | 0.60 (0.37 – 0.83) | 0.99 (0.86 – 1.17) | 0.85 (0.65 – 0.98) |
| Mg (%) | 0.295 (0.203 – 0.463) | 0.260 (0.174 – 0.350) | 0.340 (0.258 – 0.428) | 0.310 (0.269 – 0.358) |
| Zn (ppm) | 38.1 (20.1 – 49.4) | 35.8 (22.6 – 44.0) | 36.3 (21.1 – 56.5) | 37.6 (22.7 – 46.5) |
| Cu (ppm) | 9.3 (3.0 – 58.3) | 7.2 (3.9 – 29.7) | 5.2 (3.5 – 6.8) | 5.4 (3.9 – 7.7) |
| Fe (ppm) | 53.1 (35.2 – 70.5) | 47.6 (32.7 – 65.5) | 47.7 (36.1 – 61.9) | 43.4 (32.7 – 59.7) |
| B (ppm) | 15.3 (8.0 – 37.3) | 14.5 (8.4 – 47.2) | 18.9 (7.5 – 27.6) | 19.7 (6.8 – 35.2) |
| South Central | | | | |
| Ca (%) | 1.03 (0.59 – 1.37) | 0.75 (0.35 – 1.03) | 1.20 (0.76 – 1.63) | 0.88 (0.44 – 1.47) |
| Mg (%) | 0.227 (0.155 – 0.309) | 0.187 (0.120 – 0.237) | 0.302 (0.231 – 0.429) | 0.228 (0.122 – 0.386) |
| Zn (ppm) | 55.4 (28.8 – 95.5) | 42.0 (26.9 – 63.2) | 53.4 (30.2 – 82.7) | 40.6 (30.2 – 50.9) |
| Cu (ppm) | 5.4 (4.4 – 6.3) | 4.5 (3.8 – 5.0) | 4.5 (3.8 – 4.8) | 4.0 (3.9 – 4.1) |
| Fe (ppm) | 43.4 (35.5 – 53.1) | 36.1 (30.6 – 45.8) | 51.0 (42.6 – 64.7) | 35.5 (30.9 – 37.9) |
| B (ppm) | 17.8 (10.3 – 25.1) | 16.2 (13.1 (19.5) | 20.0 (14.8 – 25.8) | 17.8 (13.4 – 21.1) |
| Kenai Peninsula | | | | |
| Ca (%) | 1.31 (0.89 – 1.90) | 0.89 (0.43 – 1.15) | 1.61 (0.44 – 2.77) | 1.35 (0.47 – 1.74) |
| Mg (%) | 0.274 (0.170 – 0.446) | 0.229 (0.138 – 0.446) | 0.380 (0.202 – 0.583) | 0.209 (0.127 – 0.281) |
| Zn (ppm) | 33.3 (22.0 – 42.6) | 31.2 (22.2 – 44.0) | 48.6 (19.5 – 84.1) | 39.0 (12.4 – 71.7) |
| Cu (ppm) | 4.2 (2.4 – 5.8) | 4.0 (2.6 – 4.8) | 4.1 (2.1 – 5.8) | 4.0 (2.3 – 6.9) |
| Fe (ppm) | 48.3 (33.5 – 55.2) | 42.3 (32.7 – 55.7) | 50.6 (34.6 – 66.5) | 48.4 (37.3 – 64.2) |
| B (ppm) | 19.0 (7.2 – 30.8) | 14.8 (9.4 – 24.8) | 26.3 (7.4 – 34.5) | 22.7 (5.1 – 52.1) |

[1]Numbers in the parenthesis = range of the tested item in the samples.

As shown in the results, some nutrients were available in the soil but were not reflected in the tissue nutrient concentrations (nitrogen in Duchess in the interior). This indicated that nutrients even though in sufficient quantities in the soil were not utilized by the plants during the growing season. Therefore, there must have been other factors that affected the uptake of soil nutrients by peony roots. These may include soil physical properties such as the soil might have been too compacted for roots to penetrate, or management practices such as weed competition, or physical accessibility of roots to access the nutrient sources such as surface applied nutrients don't always make it down to the peony roots. Peony roots expand every year, as such, the plant roots increase their contact area with soil resulting in more chances to obtain soil nutrients. If the peony plant is too young (two to three years), the nutrient use efficiency is low simply because there are not enough roots to take up nutrients from soil. This suggests that nutrient application especially the inorganic nutrient sources, should be applied in relative low rate when the peony is planted.

Also, the soil mineral nitrogen concentration varies with time due to microbial consumption, or leaching/runoff. The soil mineral nitrogen concentration only serves as an index to indicate the status of available nitrogen at the time of sampling. Given the fact that there are quite a large number of growers who are using organic nutrients, a soil incubation experiment is currently being conducted for assessing the nitrogen mineralization from organic matter in the soil over the growing season. The soil samples from the incubation experiment are under laboratory analysis at this time, but the results will be reported at the annual peony growers' meeting this winter.

**Conclusions**

The survey results showed the regional differences in soil nutrient concentrations for peony production. For some of the major nutrient concentrations in soil such as phosphorus, the difference among regions was large. The study also showed the nutrient differences in soil and peony tissue between good and poor sites. However, the poor nutrient concentrations in the plant tissues did not always correspond to the low nutrient concentrations in the soil. There were other factors that may affect nutrient uptake by peonies such as weeds competing with peony plants in using available nutrients in the soil. Soil nitrogen levels appeared to be high in the interior late in the growing season. But it was not clear what will be the impact of the high nitrogen in the soil to the cut flower quality.