Programme Area: Bioenergy

Project: Characterisation of Feedstocks

Title: Final Project Presentations to ETI Slide Set - Summary of Findings from Phase 1 and Phase 2

Abstract:

This is a copy of the slide set presented by the Forest Research led team covering the findings from the whole of the Characterisation of Feedstocks Project. This set of 71 slides was presented at the ETI on 16th March 2017.

Context:

The Characterisation of Feedstocks project provides an understanding of UK produced 2nd generation energy biomass properties, how these vary and what causes this variability. In this project, several types of UK-grown biomass, produced under varying conditions, were sampled. The biomass sampled included Miscanthus, Short Rotation Forestry (SRF) and Short Rotation Coppice (SRC) Willow. The samples were tested to an agreed schedule in an accredited laboratory. The results were analysed against the planting, growing, harvesting and storage conditions (i.e. the provenance) to understand what impacts different production and storage methods have on the biomass properties. The main outcome of this project is a better understanding of the key characteristics of UK biomass feedstocks (focusing on second generation) relevant in downstream energy conversion applications, and how these characteristics vary by provenance.

Biomass feedstock characterization
Final synthesis report

Helen McKay, Geoff Hogan: Forest Research
Steve Croxton: Uniper Technologies Ltd

16th March 2017

Thanks to....

Authors

FR: Helen McKay, Geoff Hogan, Michael Wall, Tom Connolly, Jack Forster.

Uniper: Steve Croxton, Susan Weatherstone, Will Quick,

Acknowledgements:

FR: Liz Richardson, Mark Oram and Alistair McLeod

Uniper: Stuart, Duncan

Purpose

- **The overall purpose of the contract (Characterisation of Biomass Feedstocks) is to inform the ETI on the variability in feedstock properties of UK-produced energy biomass types and the causes.**
- **The specific objective of this presentation is to provide a succinct and concise summary of the key findings of the entire contract and in addition draw out the practical implications for both growers and operators of conversion plants.**

What did we do first?

In Phase 1 - four related studies to investigate :

- the extent of variation of physical and chemical characteristics both between and within biomass feedstock types
- the reasons behind any observed variation in feedstock characteristics. Potential sources of variation included were climate zone, soil type, harvest time, storage, and plant part
- feedstock variability within a site (*Miscanthus* and one variety of willow SRC only)
- leaf properties (poplar SRF and willow SRC) for comparison to the feedstocks containing little or no leaf material
- pellet properties since the process of pelletising may alter the composition cf. the raw feedstock.

The findings are described in detail in D6 and associated appendices.

What did we do first? – in detail

Feedstock	Climatic zone	Soil types	Harvest Time	Plant part	Time of Sample
Study 1: Variability and its determinants					
Miscanthus	Warm/dry Warm/moist	Light Medium	February to April	whole	at harvest in-field prior to baling 1 month stored as bales
Willow SRC	Warm/dry Warm/moist	Light Medium	February to May	whole	at harvest 1 month stored as chips
Poplar SRC	Warm/dry	Light Medium	June	whole	at harvest
Poplar SRF	Warm/dry Warm/moist	Light Medium	April July/August	trunk tops	at harvest 3 months stored
Spruce SRF	Warm/moist Cold/wet	Light mineral Light organic Light peat	March June	trunk tops	at harvest 3 months stored
				bark	at harvest
Study 2: Within-field variation					
Miscanthus	Warm/dry	Light	March/April	whole	at harvest
Willow SRC	Warm/dry	Light Medium	March	whole	at harvest
Study 3: Leaves					
Poplar SRF	Warm/dry Warm/moist	Light Medium	July/August	leaves only	In full leaf
Willow SRC	Warm/dry	Light Medium	September	leaves only	In full leaf
Study 4: Pelleting					
Miscanthus	n/a	n/a	n/a	whole	before and after pelleting

What did we do next?

In Phase 2 there were four studies designed to follow up on points of particular interest in Phase 1

- impact of harvest time on *Miscanthus* properties
- impact of harvest time on willow SRC properties
- impact of variety on willow SRC characteristics
- possible effects of four different, but commonly used methods for storing *Miscanthus* bales, to understand the changes in fuel quality during 6 months of storage.

The findings are described in detail in D12 and associated appendices

All data are contained in D11

What did we do next? – in detail

Feedstock	Climatic zone	Soil types	Harvest Time	Varieties	Time of Sample
Study 5: The impact of harvest time on the feedstock characteristics of *Miscanthus*					
Miscanthus	Warm/dry (n=6)	Light (n=3) Medium (n=3)	4 to 9.11.2015 4 to 12.01.2016 7 to16.03.2016 22.03 to 10.05.2016 27.04 to 26.05.2016	*Miscanthus x giganteus*	3 simulated harvests 1 sampling at commercial harvest 1 sampling pre-baling
Study 6: The impact of harvest time on the feedstock characteristics of willow SRC					
Willow SRC	Warm/dry (n=5) Warm/moist (n=1)	Light (n=5) Medium (n=1)	9 to 24.11.2015 8 to 25.01.2016 14 to 23.03.2016	Representative mix of commercial varieties	3 simulated harvests
Study 7: The impact of variety on the feedstock characteristics of willow SRC					
Willow SRC	Various (n=5)	Various (n=5)	29.02 to 3.03.2016	Endurance Tora Terra Nova Resolution Sven Nimrod	1 simulated harvest
Study 8: The impact of storage system and duration on the feedstock characteristics of *Miscanthus*					
Miscanthus	Warm/moist (n=1)	Medium (n=1)	18.4.2016	*Miscanthus x giganteus*	4 different storage systems – sampled monthly. May – November 2016

What did we test?

1. The feedstocks examined range from *Miscanthus*, through woody deciduous plants grown for only a few years and regenerated by coppicing (willow and poplar), to small deciduous and evergreen trees (poplar and Sitka spruce respectively). It is therefore hypothesised that the feedstocks will differ in their fuel properties and/or composition.

2. With the exception of the *Miscanthus*, the feedstocks are differentiated into plant parts that have different functions, e.g. mechanical support versus photosynthesis; therefore we hypothesise that these plant parts will differ in their fuel properties and/or composition.

3. Feedstock properties will differ depending on the climate the crop is exposed to

What did we test?

4. Feedstock properties will differ depending on the soil composition and characteristics of the site.

5. Feedstock properties will differ according to the time of year that the biomass is harvested.

6. Feedstock properties will change with storage.

7. Within a given field, feedstock properties will be relatively uniform.

8. The process of pelletisation will influence the fuel properties and/or composition.

What did we test?

9. Harvest time will affect the fuel properties and/or composition of *Miscanthus* and willow SRC.

10. The feedstock characteristics of *Miscanthus* and willow SRC will differ from one year to the next at a given site.

11. The feedstock characteristics of willow SRC varieties will differ from one variety to another in a consistent manner from one location to another.

12. The fuel properties and/or composition of *Miscanthus* are influenced by the storage method and duration.

What did we measure?

For the purpose of this study, the analysis options were:

A Proximate and ultimate analyses (moisture, ash, volatile matter, net calorific value, gross calorific value, sulphur, chlorine, carbon, hydrogen, nitrogen)

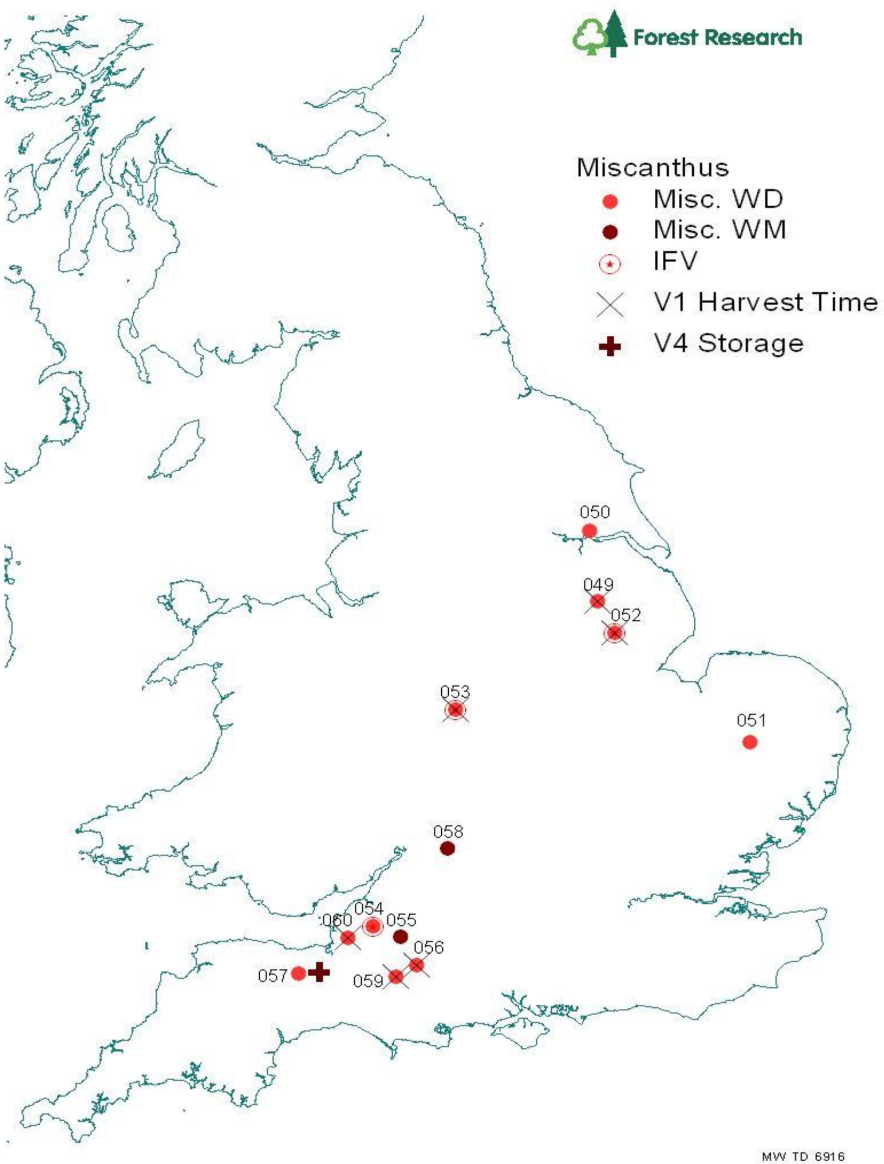
B Ash composition (SiO_2, Al_2O_3, Fe_2O_3, TiO_2, $CaCO_3$, MgO, Na_2O, K_2O, Mn_3O_4, P_2O_5, BaO) plus trace metals (Ba, Be, Cr, Co, Cu, Mo, Ni, V, Zn)

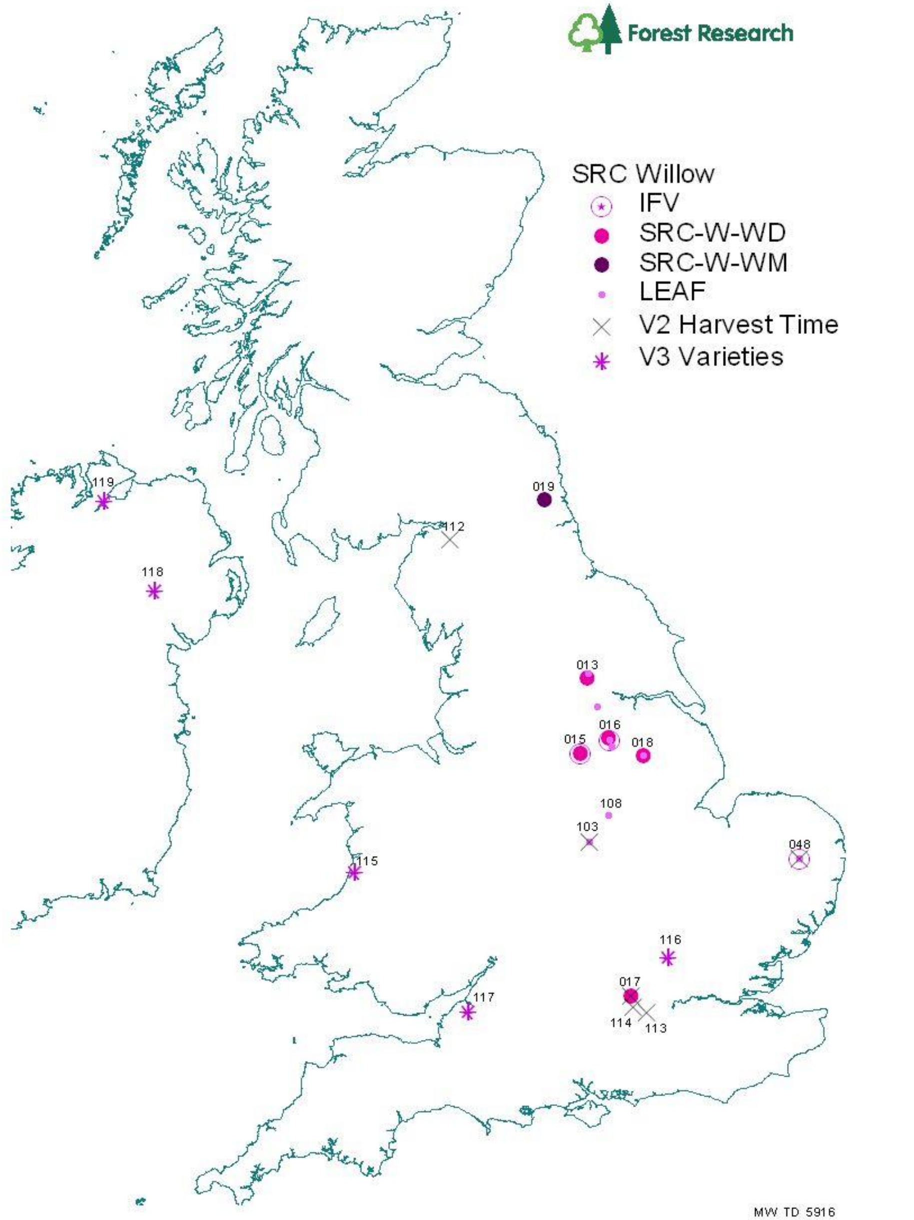
C Extended trace metals (Hg, Pb, Cd, As, Se, Sb)

D Additional halides (bromine and fluorine)

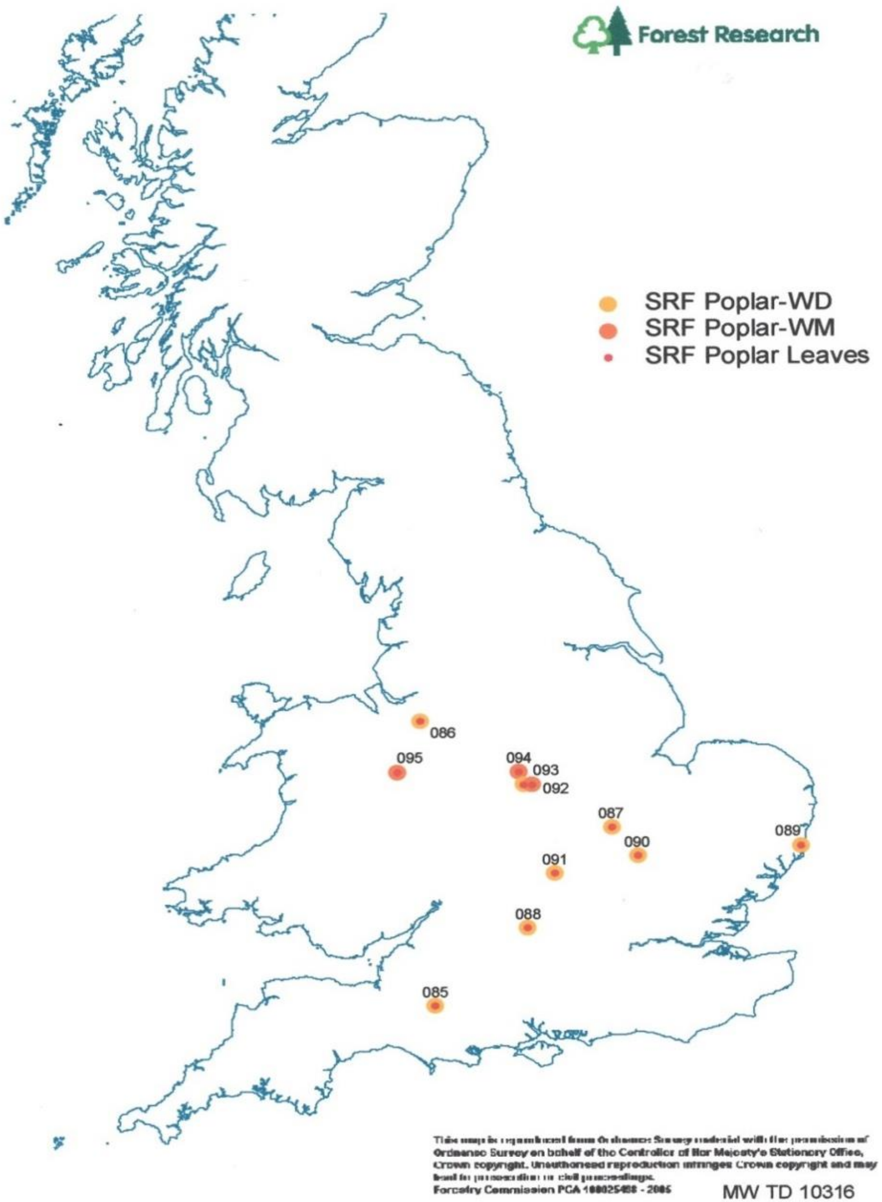
E Ash fusion temperatures.

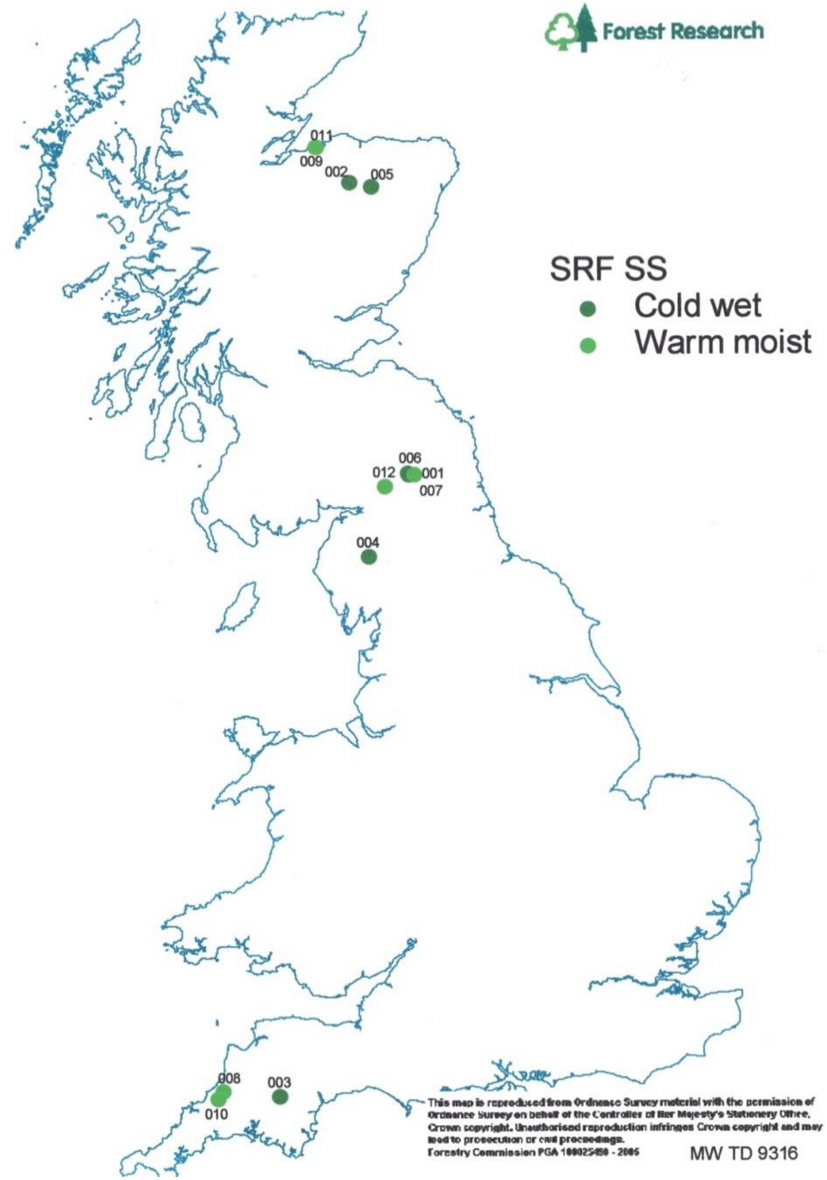
Locations of sample sites





Locations of sample sites





Protocol

Key elements	Current proposal
Species	*Miscanthus* bales from one location (192 bales, ca. 100 fresh tonnes)
Location	Taunton
Age	<1 year beginning from time of baling
Storage systems (4)	1. Outside uncovered 2. Outside covered by sheet 3. Outside covered by a roof but no sides 4. Inside storage.
Storage duration	Intended for up to 6 months *
Treatments (2)	A. Unmoved: bales will be placed into storage and not moved again until the stack is dismantled. Samples will be taken at the start and end of the process. B. Moved monthly: bales will be placed into storage and dismantled each month for sampling,

Corer

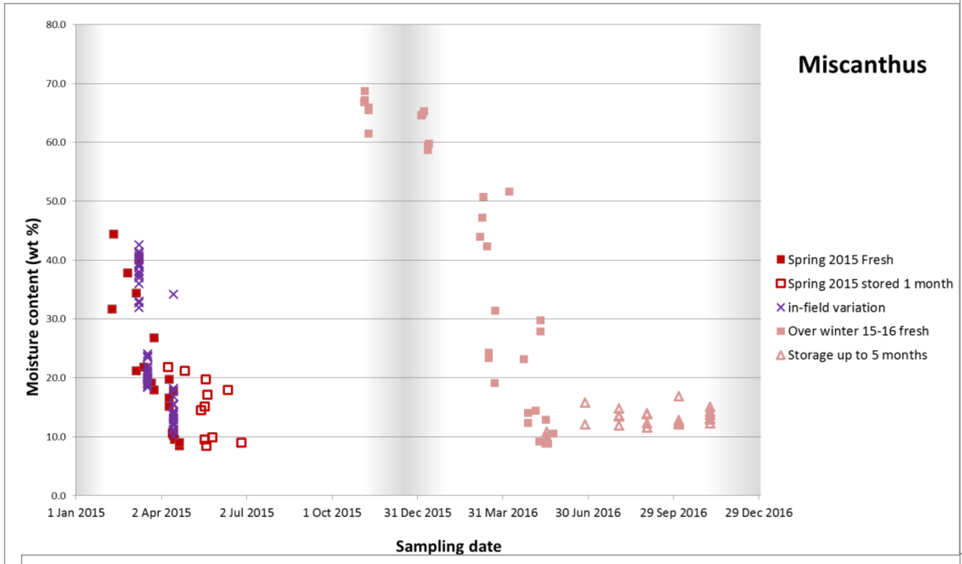
Storage treatments

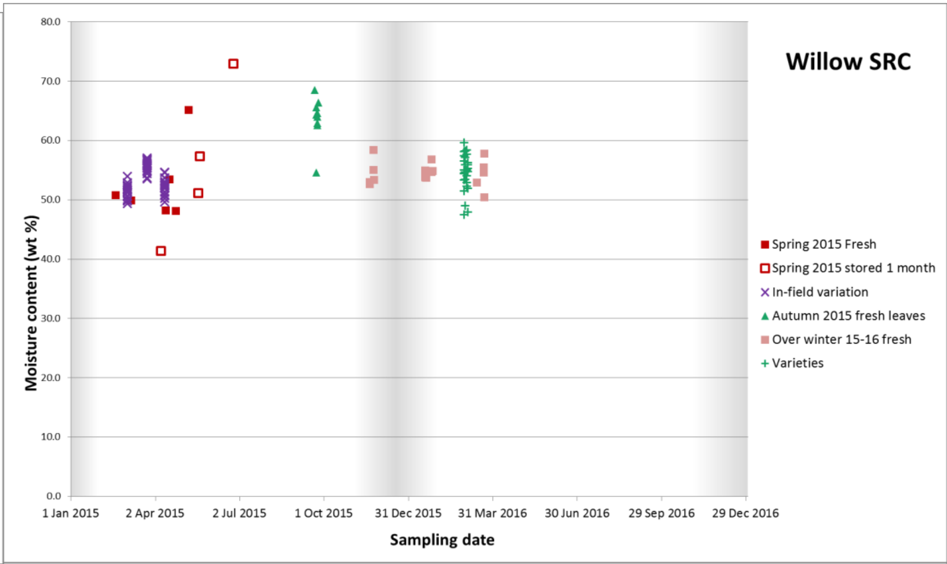


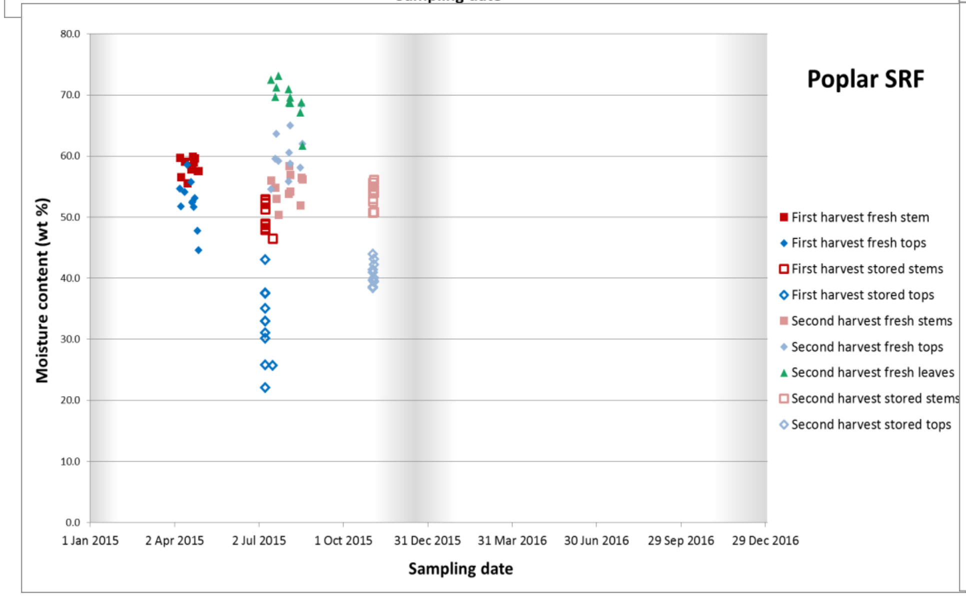

Collated results

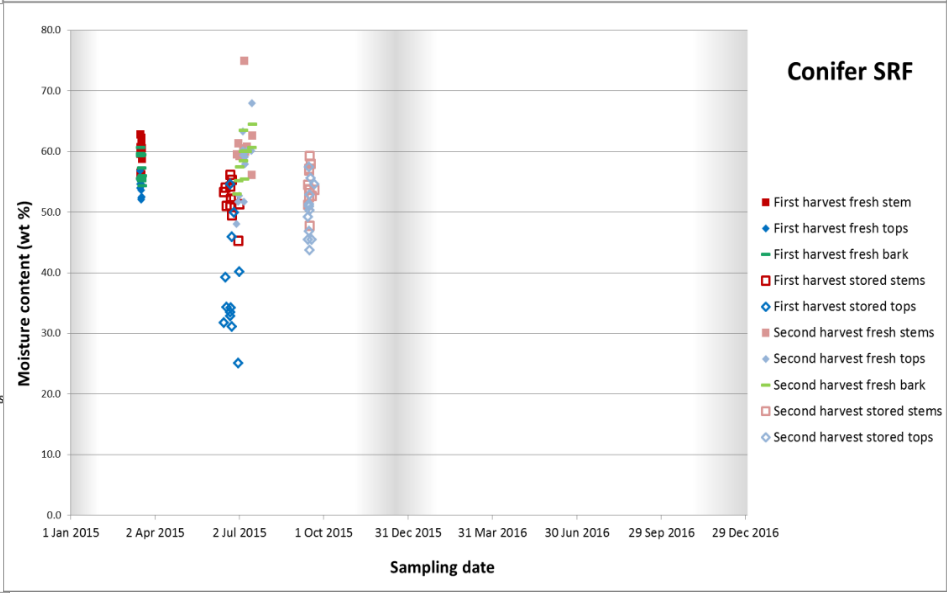
MOISTURE	Units of % wt in as received fuel
General	*Miscanthus:* Dominated by seasonal effects, falling from 30-40 to 10-20 in spring 2015 and from 60-70 to 10-20 in winter 2015 through to spring 2016 Willow SRC, poplar SRF and conifer SRF generally lay between 50 and 60.
Source of variation	
Climate zone	*Miscanthus:* Willow SRC: Poplar SRF: Conifer SRF:
Soil type	*Miscanthus:* Willow SRC: Poplar SRF: Conifer SRF:
Storage	*Miscanthus:* In Phase 2 storage had over a long period increased moisture content (MC) slightly from the very low initial level at baling; in Phase 1 there was a small additional fall in MC in the one month following baling Willow SRC: Erratic response with some increases and some decreases; no pattern over the limited period of outdoor uncovered storage. Poplar SRF: Moisture decreased especially the tops (56 to 36) Conifer SRF: Moisture decreased especially the tops
Location within field	*Miscanthus*: variation between fields was greater than within fields. Range within fields ca 10 units which was similar to the site-site and seasonal differences Willow SRC: variation between fields was greater than within fields. Range within fields < 5 units which was slightly less than the site-site differences
Plant part	Willow SRC leaves had slightly higher moisture contents than stem samples. For poplar in spring, stems tended to have a higher moisture content than the tops but in summer moisture increased in the order stems < tops< leaves. For conifer plant parts differed by only 10% and there was little difference between plant parts.
Season	*Miscanthus:* major impact of season, with moisture content declining over autumn, winter and spring Willow SRC: little seasonal change Poplar SRF: little seasonal change in stems but tops in summer had higher moisture content than in spring (51 vs 42) Conifer SRF: little seasonal change
Variety	Varietal differences were large, exceeding seasonal differences. Endurance had the lowest moisture content while Nimrod and Terra Nova had the highest moisture content.

Composite figures

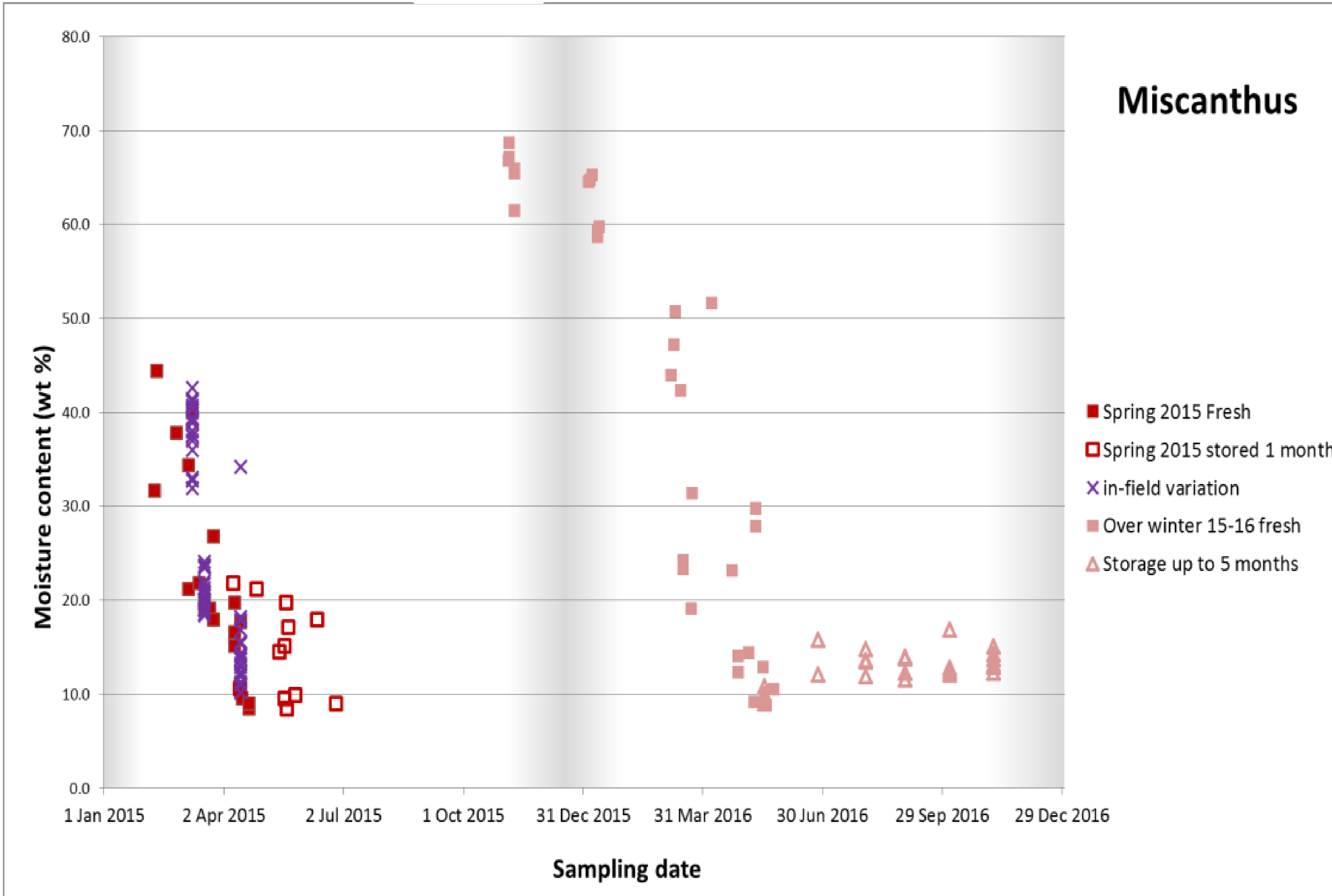








Composite results

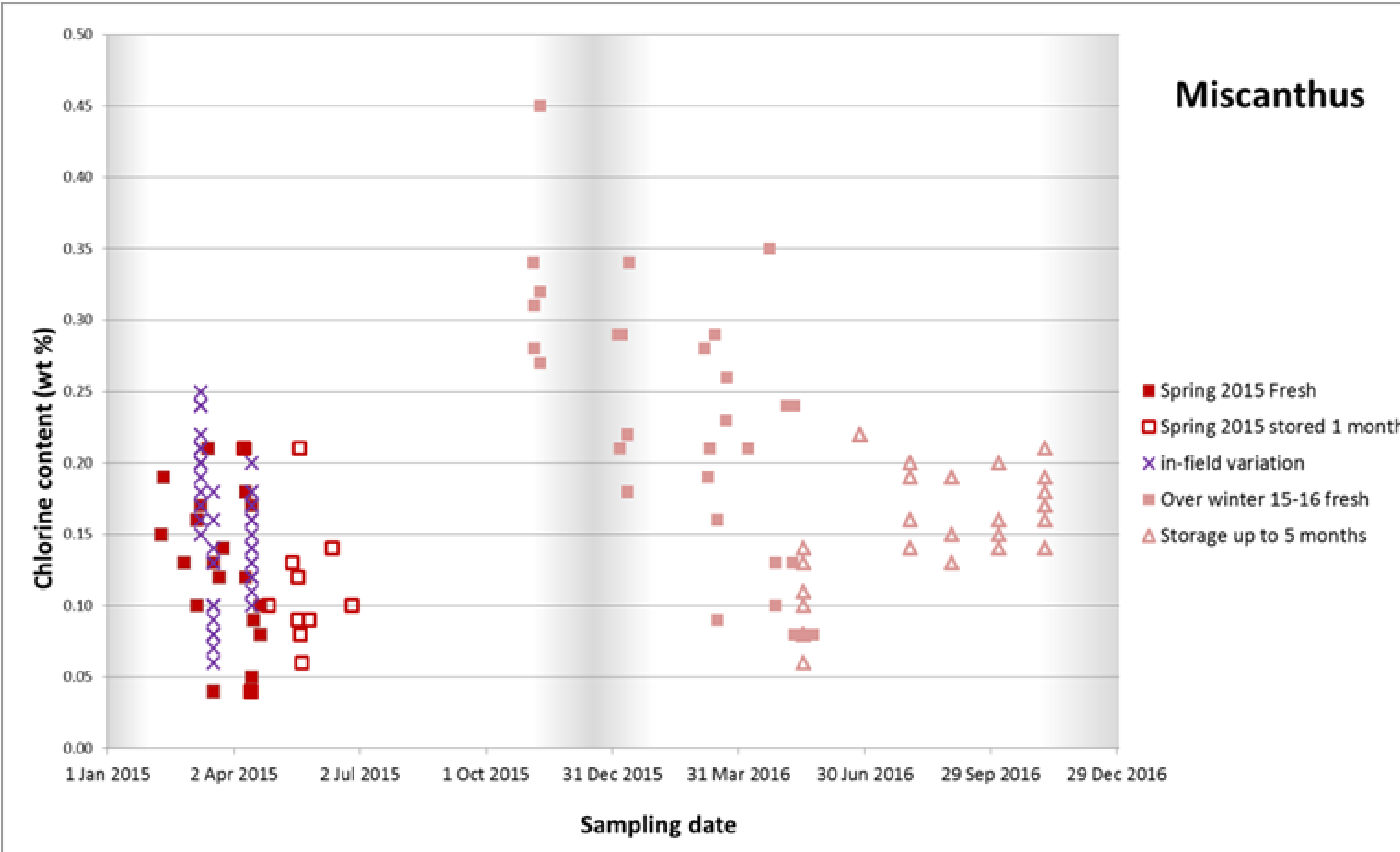


Hypothesis 1

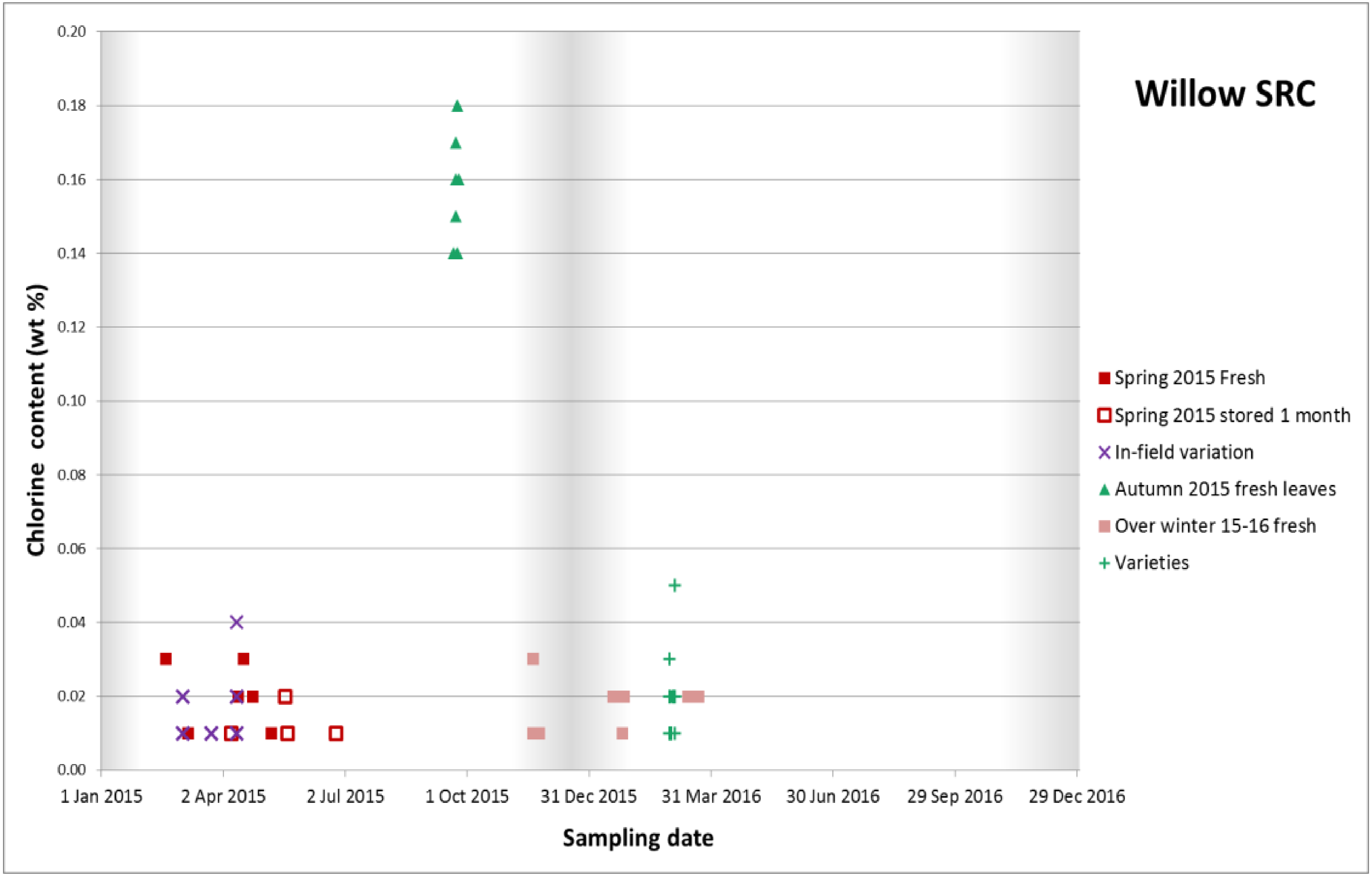
The feedstocks examined range from Miscanthus, through woody deciduous plants grown for only a few years and regenerated by coppicing (willow and poplar), to small deciduous and evergreen trees (poplar and Sitka spruce respectively), therefore we hypothesise that the feedstocks will differ in their fuel properties and/or composition.

Significant variation was seen between the different feedstocks in terms of their fuel properties and composition in terms of both the means and the range of the data. For example, the *Miscanthus* showed higher levels of chlorine than the spruce SRF.

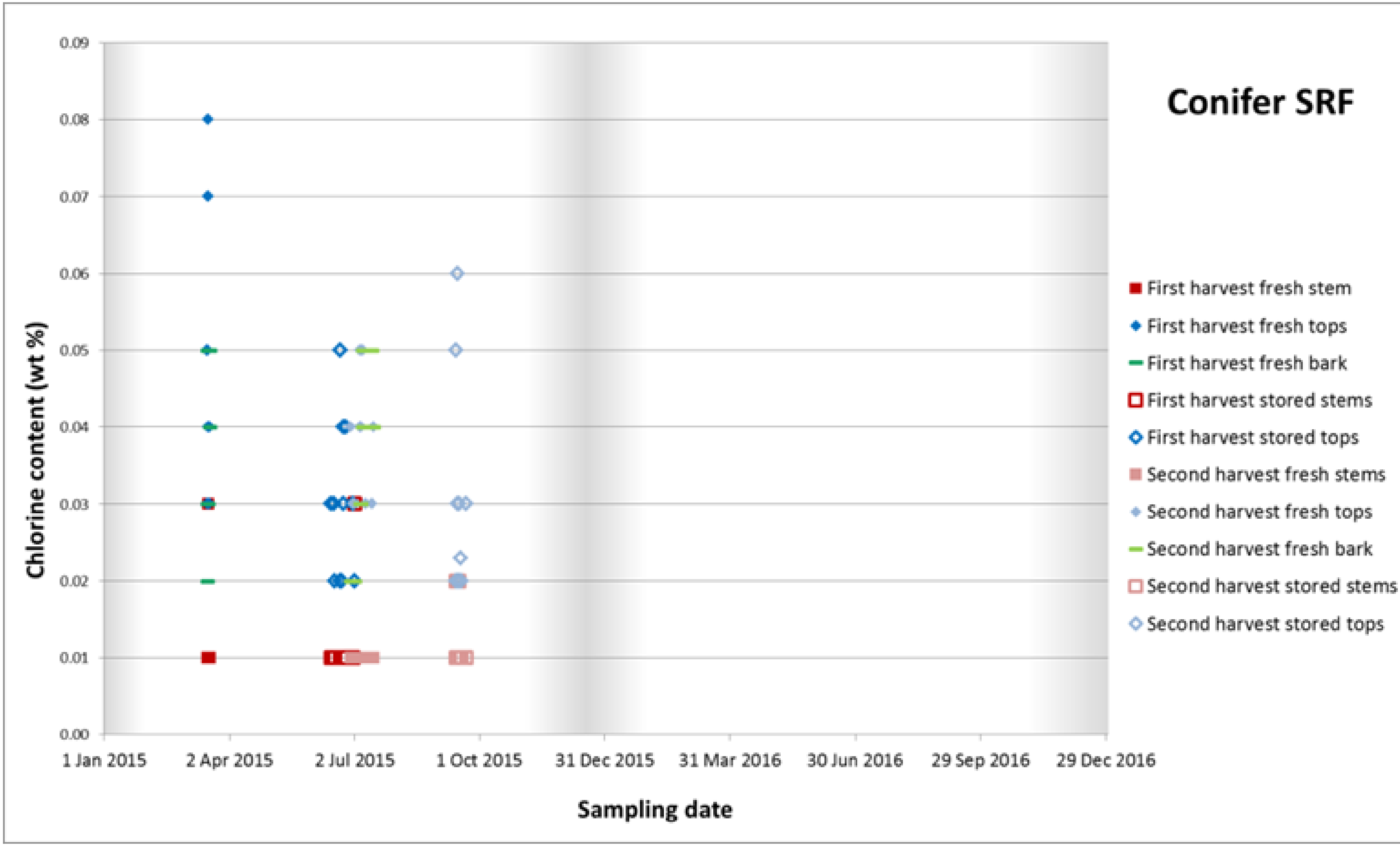
Chlorine in *Miscanthus*



Chlorine in willow SRC



Chlorine in conifer SRC

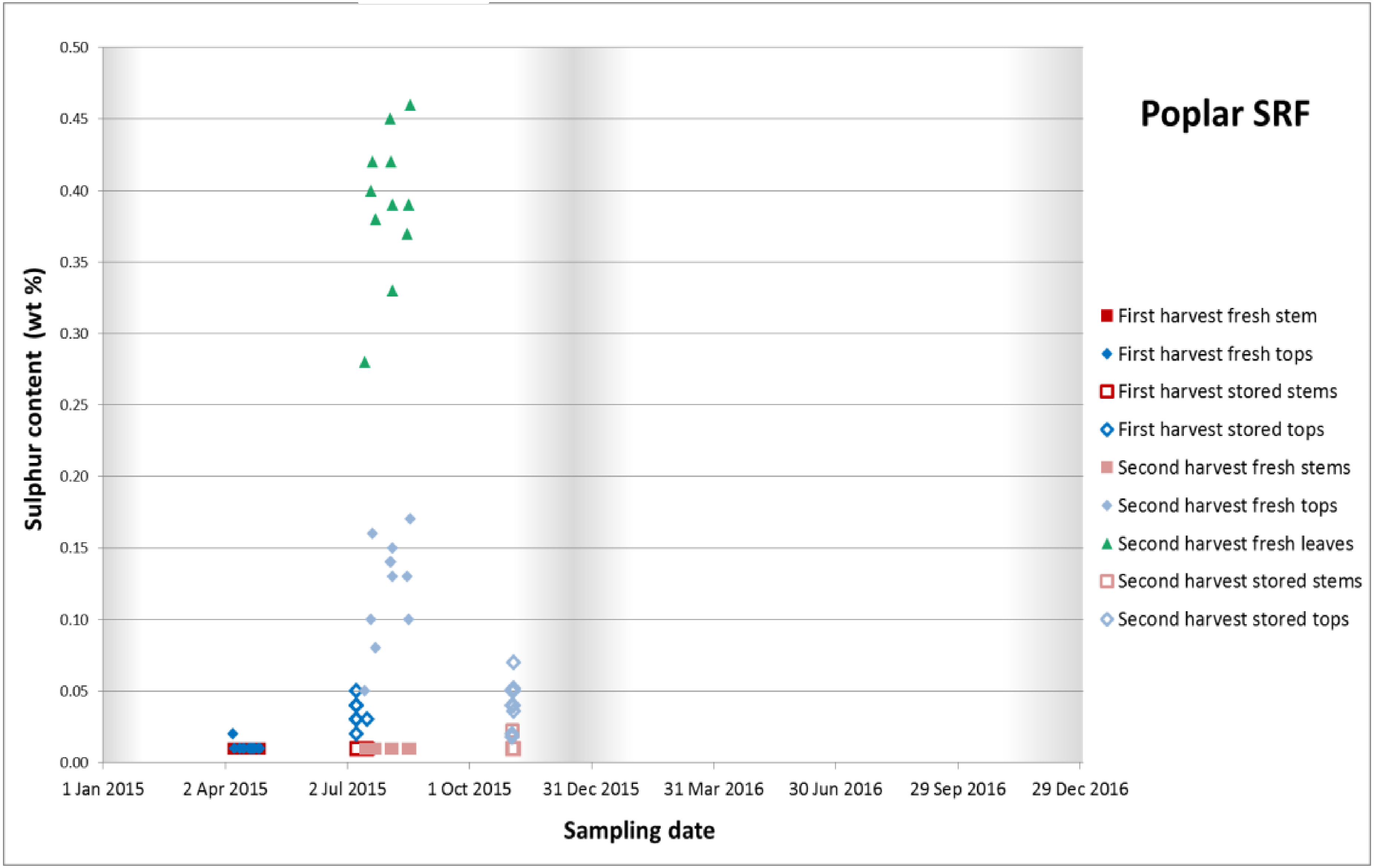


Hypothesis 2

Plant parts will differ in their fuel properties and/or composition.

This hypothesis was investigated for willow SRC, poplar SRF and spruce SRF and the results indicated that plant part did have a significant impact. Generally, levels of chemical elements were highest in the leaves (where analysed), followed by the tops and bark.

Sulphur in poplar SRF



Hypothesis 3, 4

Feedstock properties will differ depending on the climate the crop is exposed to. Within the range of average climate zones covered in the project, climate zone had little influence on fuel composition.

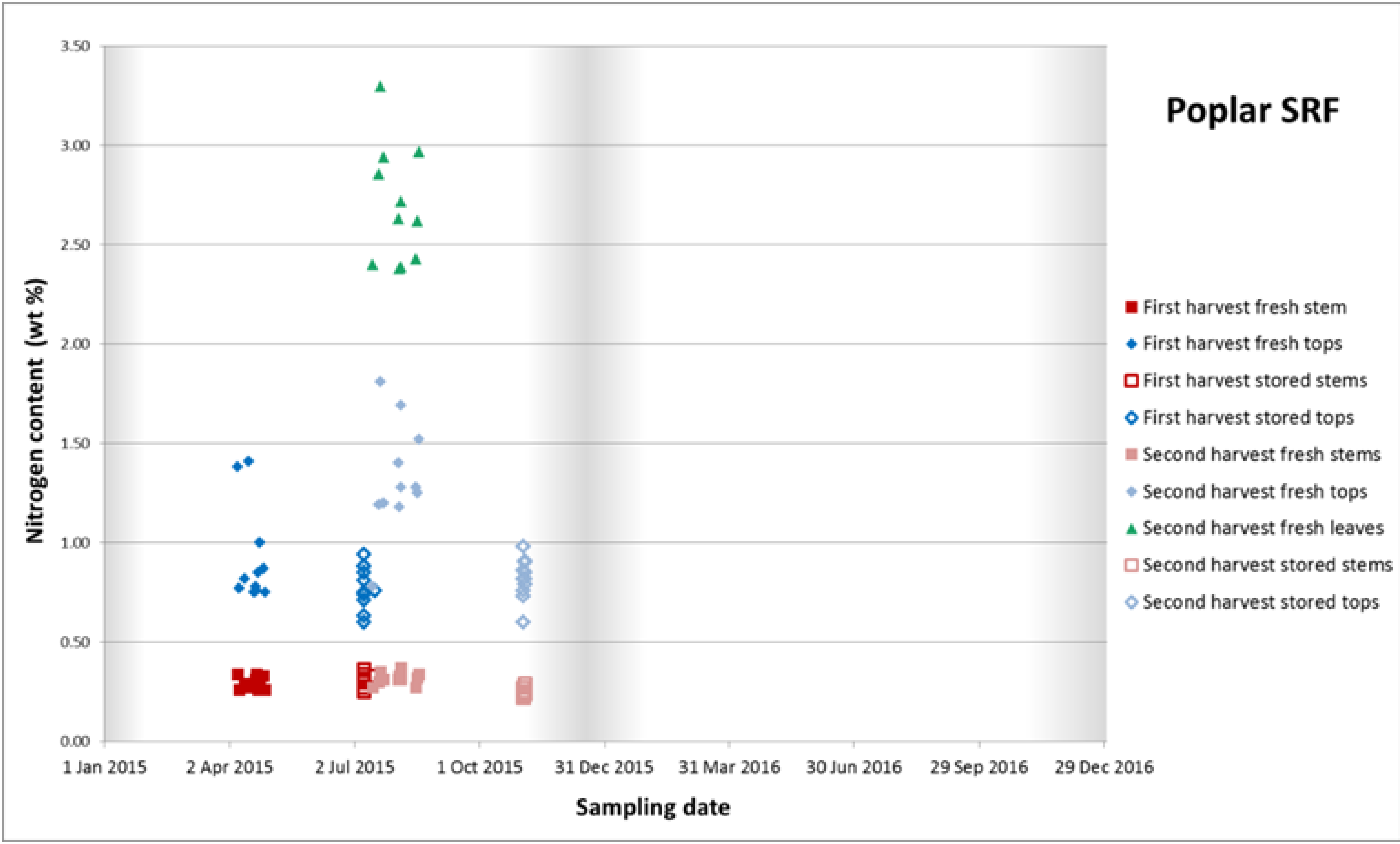
Feedstock properties will differ depending on the soil composition and characteristics of the site. Within the range of soil types determined in the project, soil type had very little influence on fuel properties and/or composition. Similarly, the analysed soil parameters showed few correlations with the corresponding feedstock composition.

Hypothesis 5

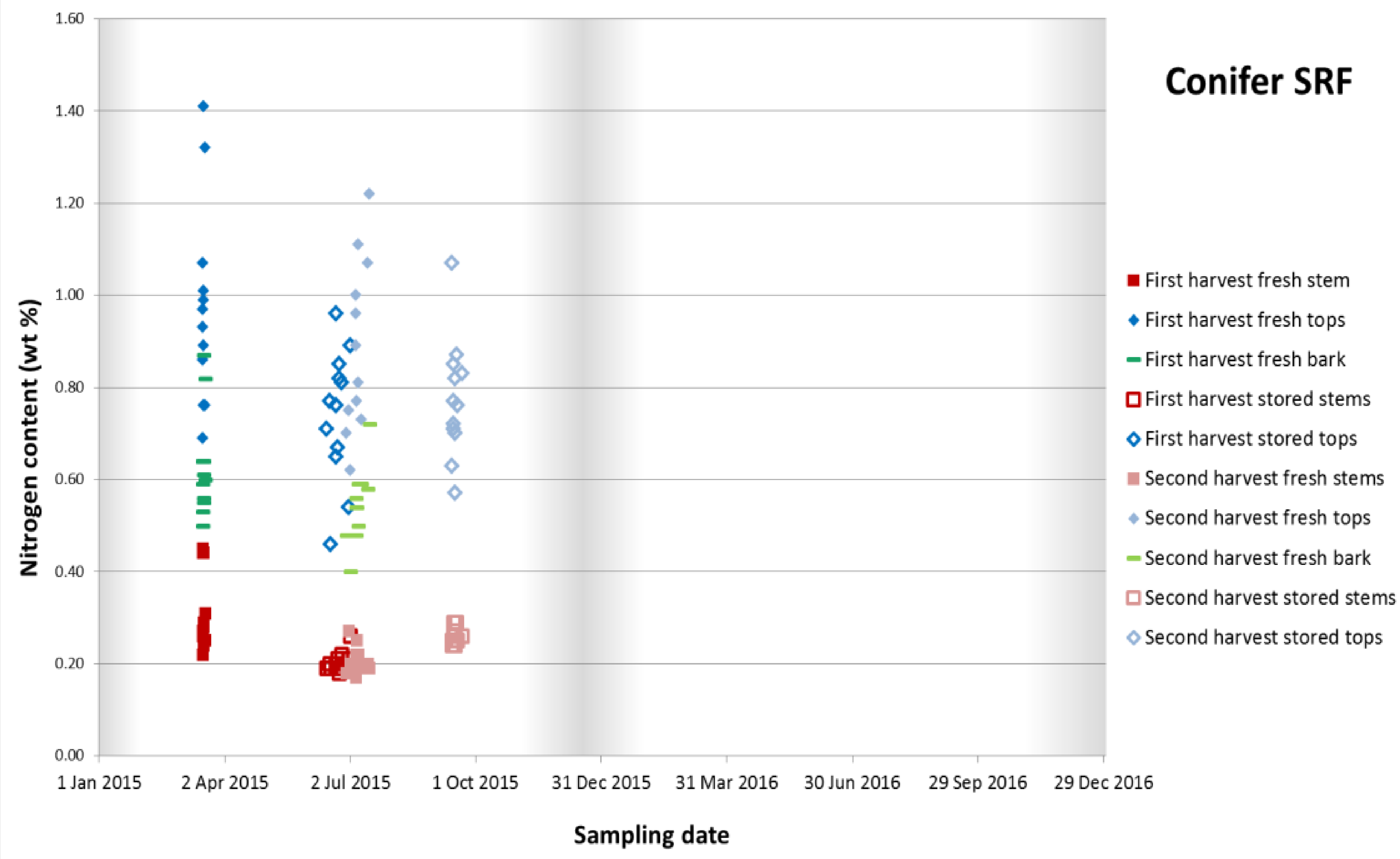
Feedstock properties will differ according to the time of year that the biomass is harvested.

In Phase 1 this question focussed on poplar and spruce SRF. Feedstock properties of both did differ when harvested in the spring compared to summer harvests, with an impact on the poplar SRF particularly apparent. These differences were more pronounced for the tops than the lower part of the stem; for the poplar SRF this may be due to the inclusion of leaves in the second tops harvest that are essentially absent from the first harvest.

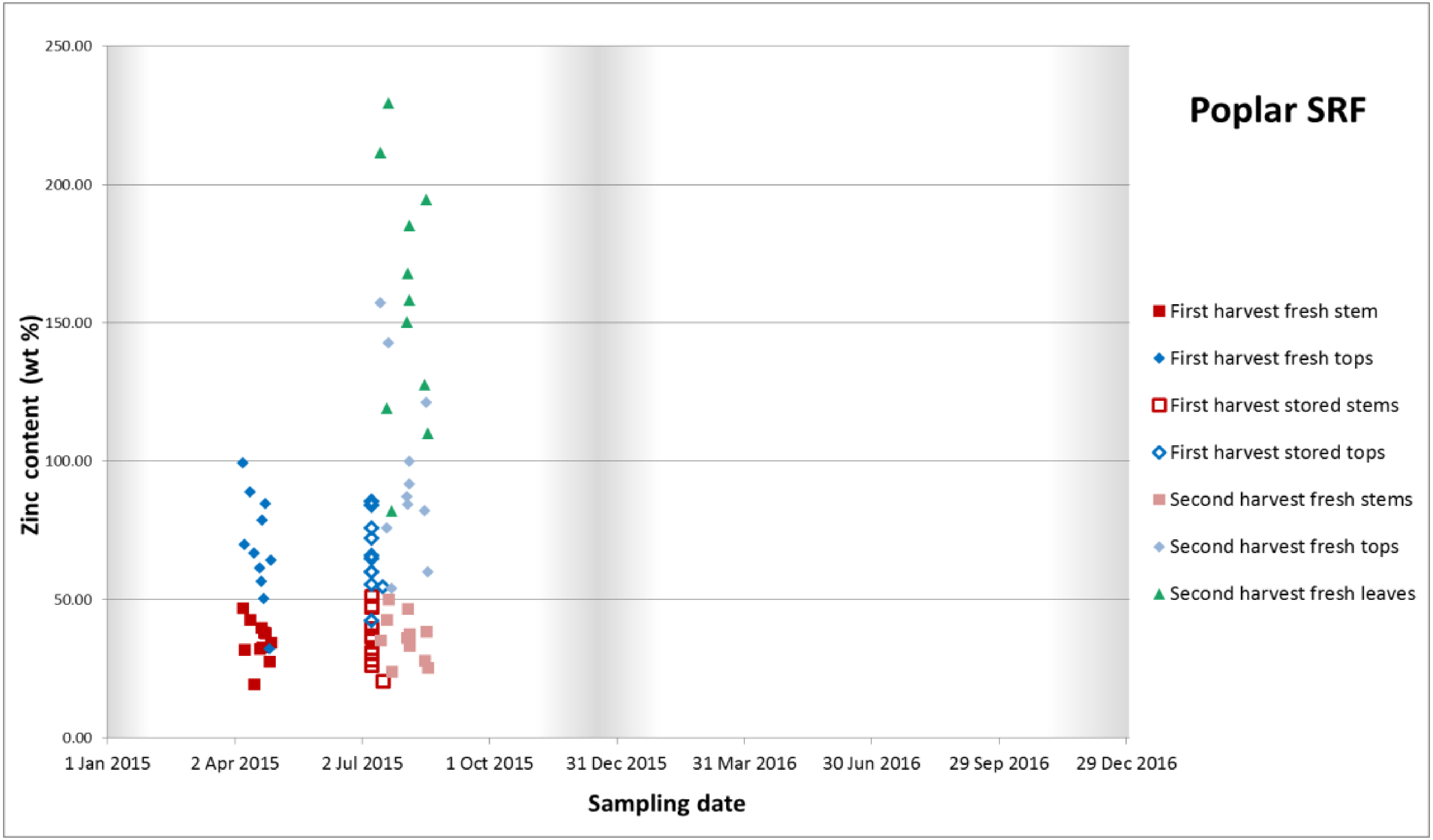
Nitrogen in poplar SRF



Nitrogen in conifer SRF



Zinc in poplar SRF



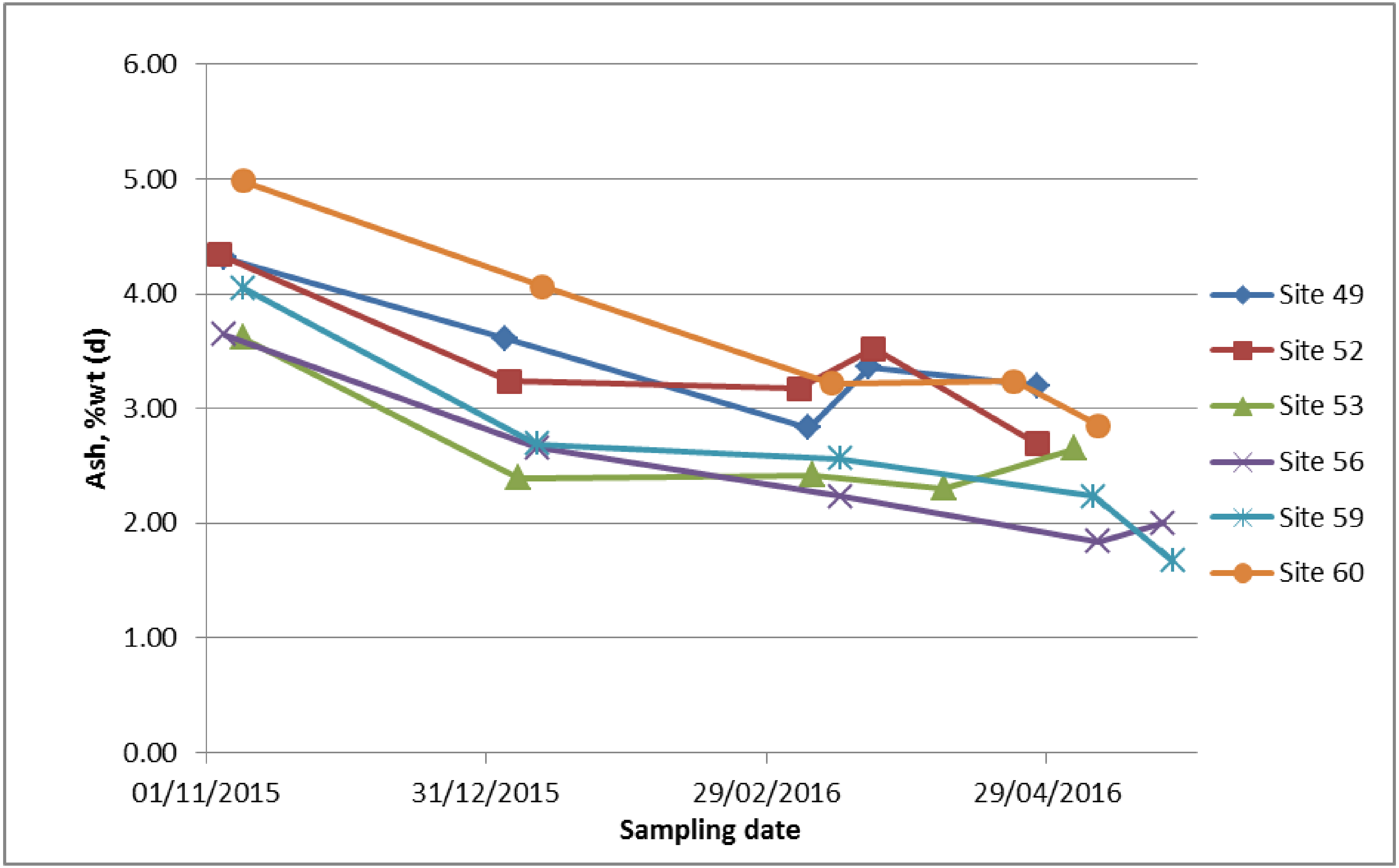
Hypothesis 9

Harvest time will affect the fuel properties and/or composition of Miscanthus and willow SRC (Phase2).

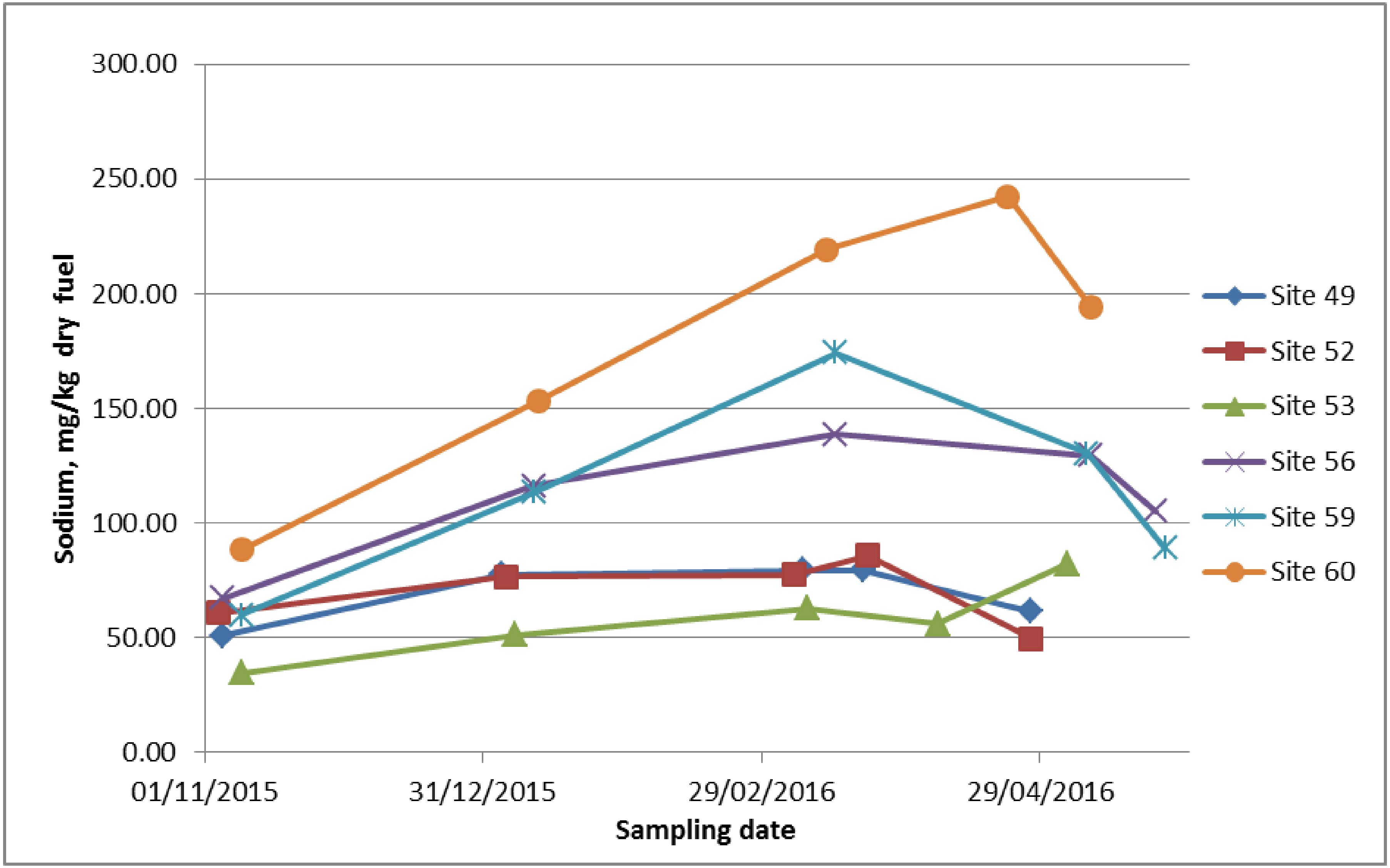
Miscanthus a general decrease through late autumn, winter and early spring was observed in moisture content, ash, carbon, nitrogen, chlorine, molybdenum, zinc, bromine, phosphorus, silicon, and calcium accompanied by an increase over the same period in net calorific value, volatile matter, and sodium.

Willow SRC: only a few characteristics differed across three simulated harvesting times – gross calorific value, chromium, and calcium carbonate, potassium oxide and phosphorus - with the majority showing no difference.

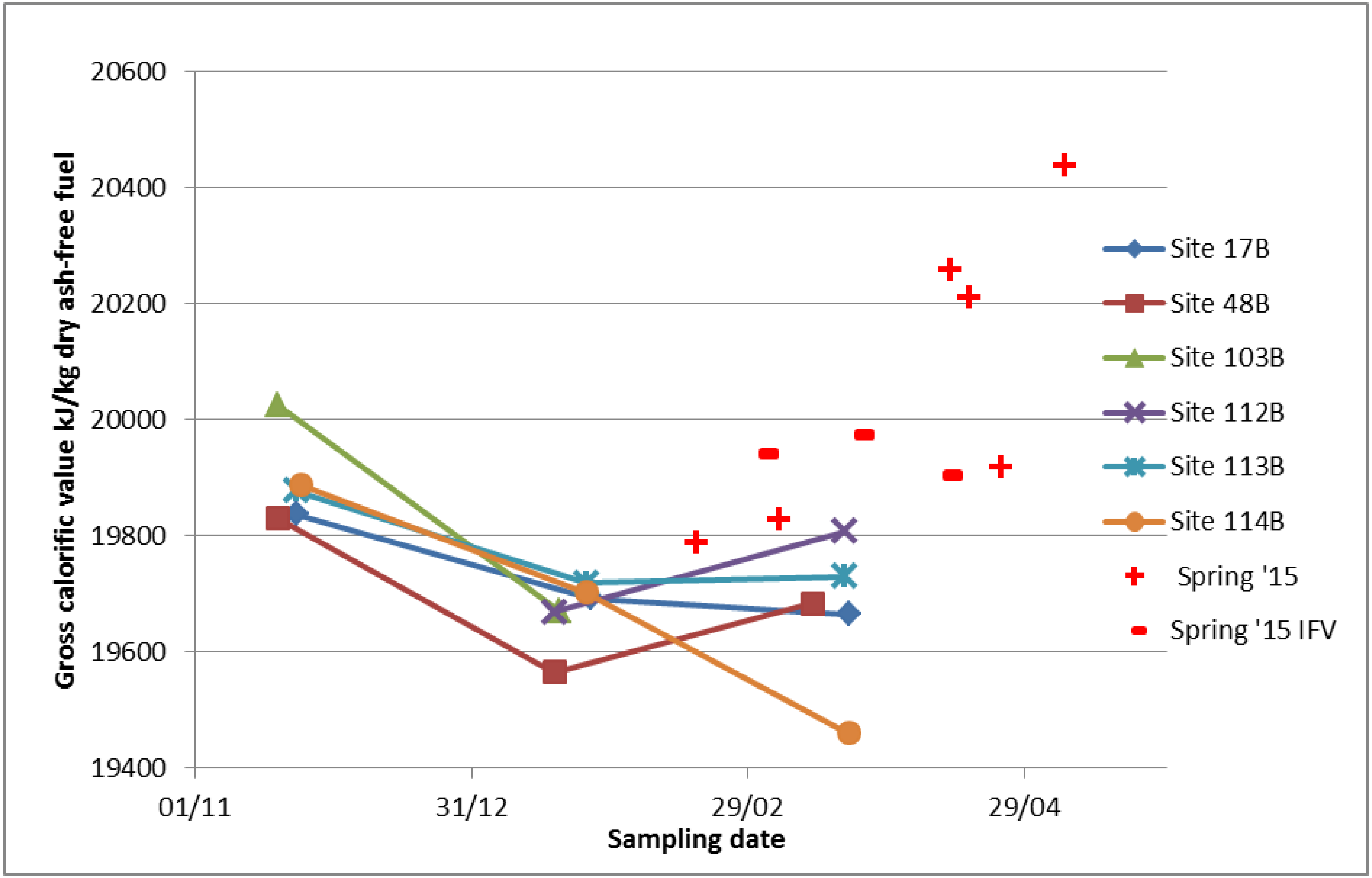
Ash in *Miscanthus*



Sodium in *Miscanthus*



GCV in willow SRC



Hypotheses 6, 12

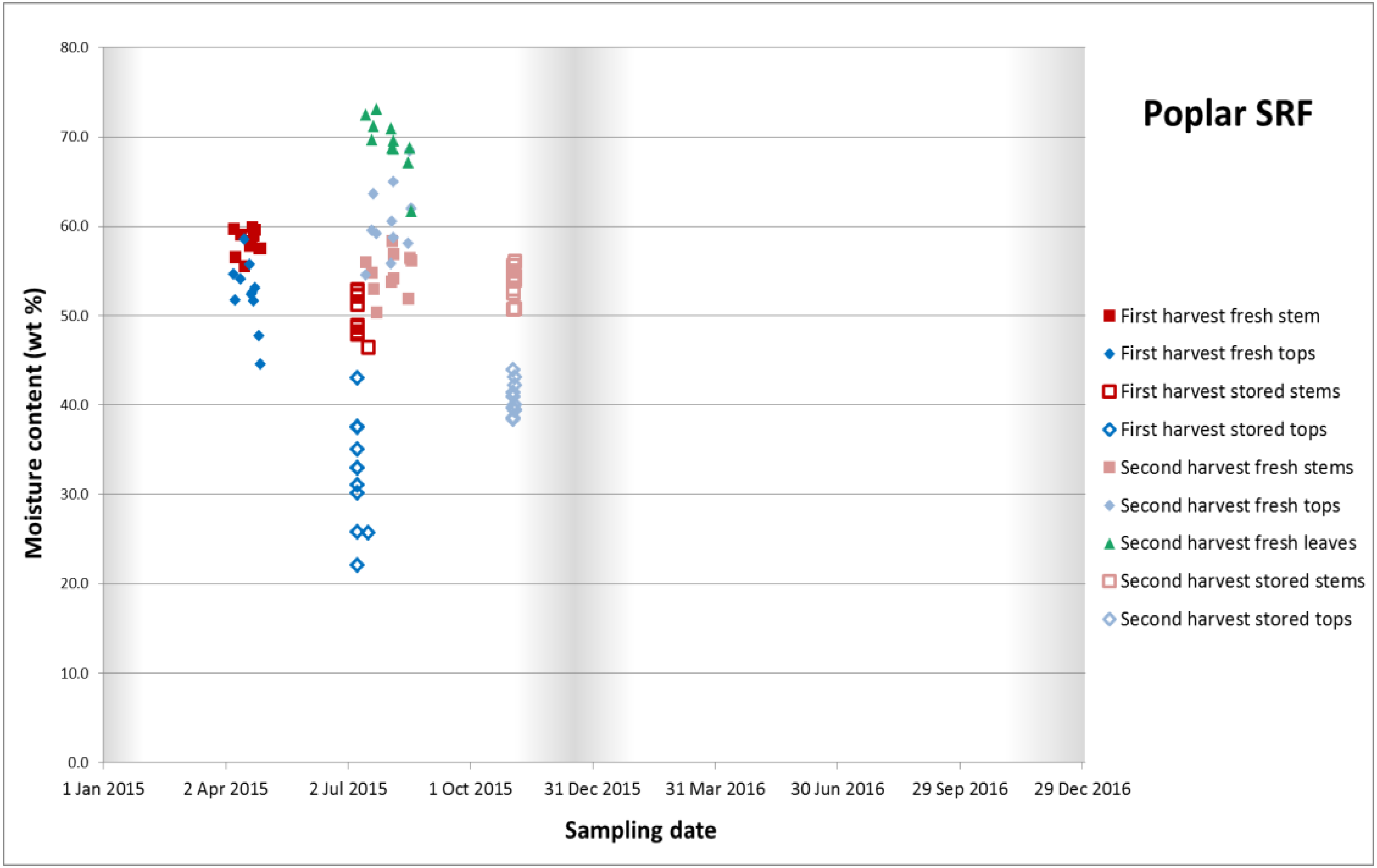
Feedstock properties will change with storage.

Storage had a strong influence on most feedstocks, particularly for moisture content and related properties for poplar SRF and spruce SRF.

The fuel properties and/or composition of *Miscanthus* are influenced by the storage method and duration.

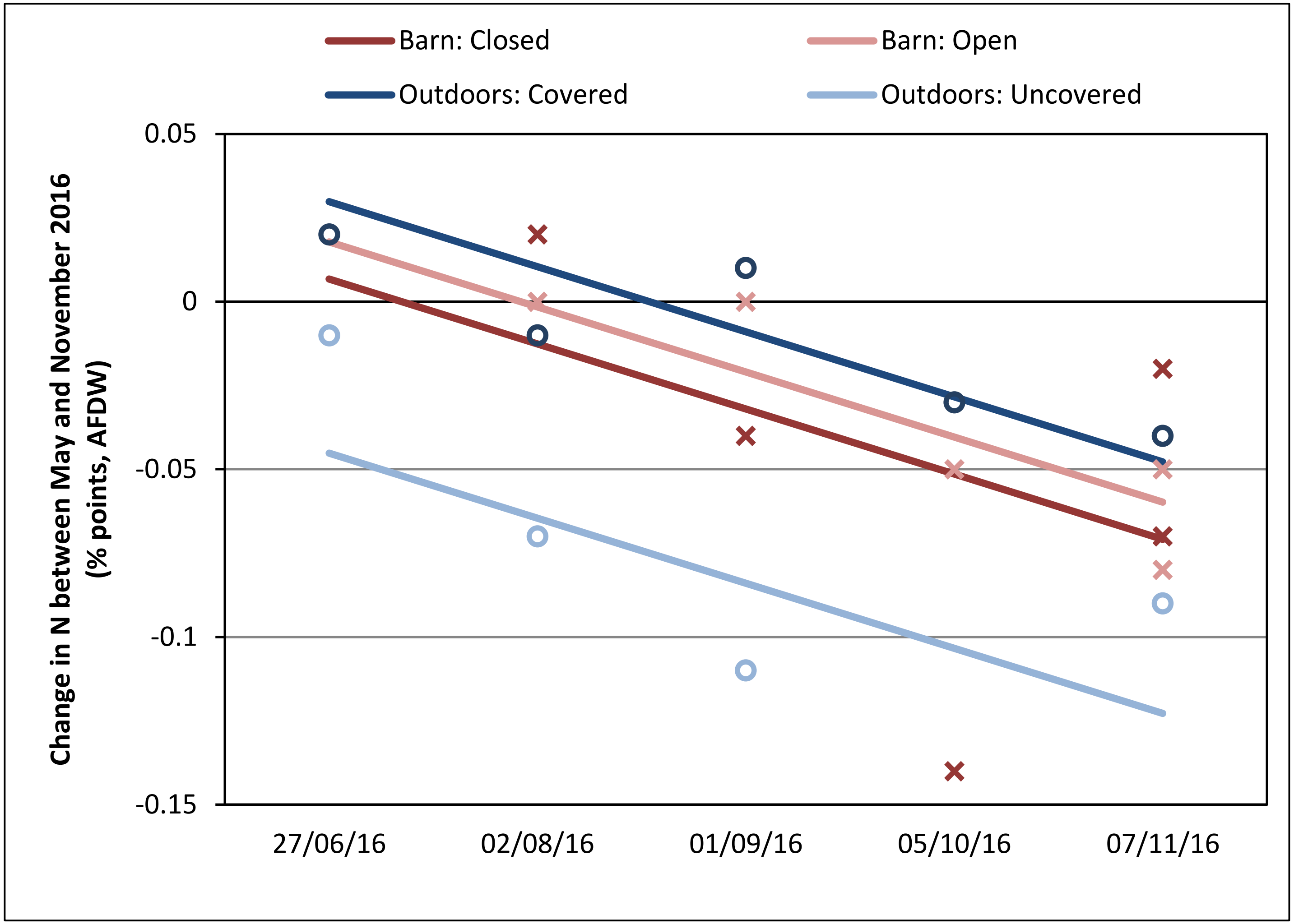
- 14% of analysed feedstock characteristics (included ash, nitrogen, sulphur, zinc, bromine and calcium) storage treatments did have a significant influence;
- 43% were affected by storage but there was no influence of storage treatment
- 43% of the feedstock characteristics tested were not significantly affected by storage

Moisture in poplar SRF

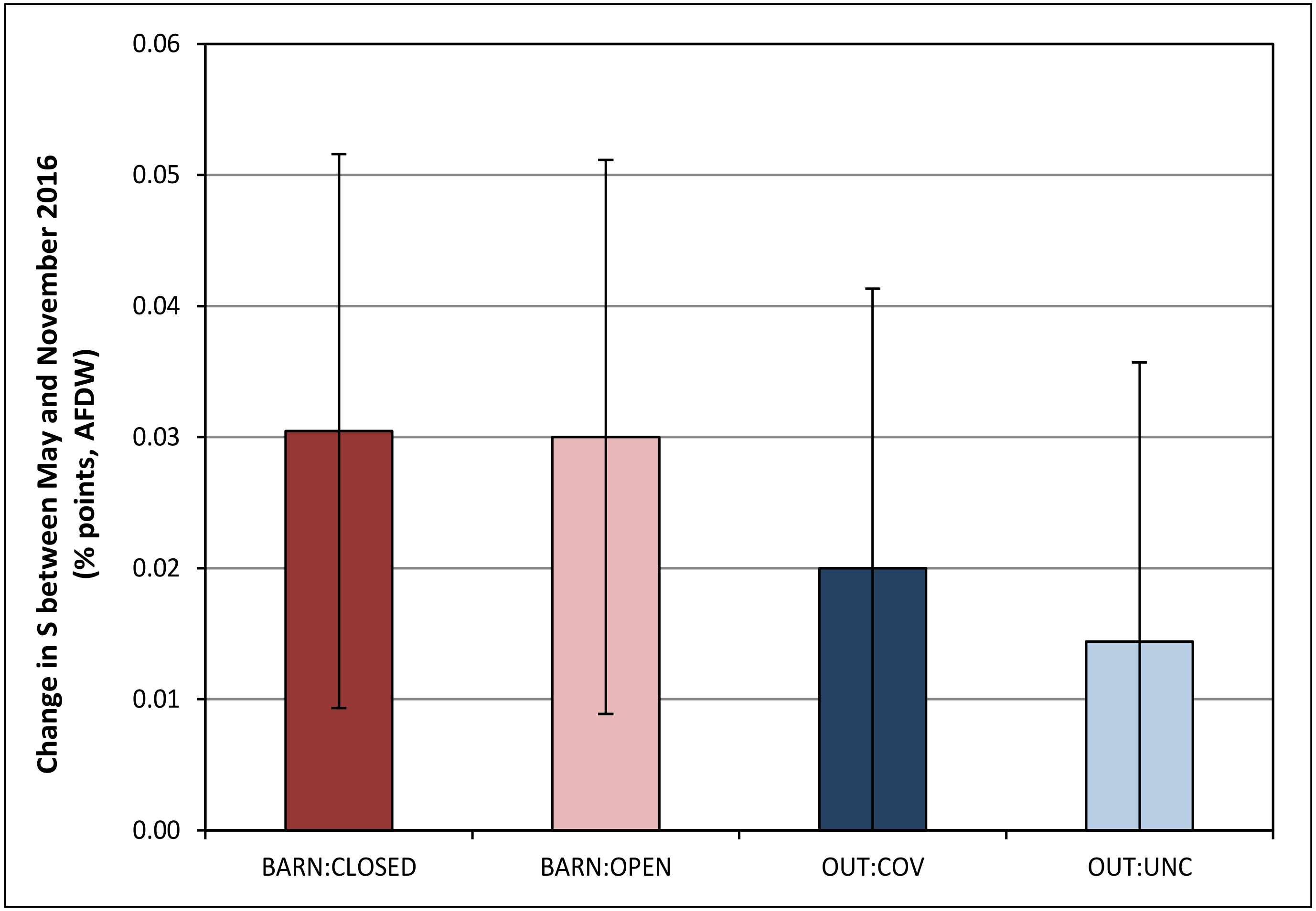


Nitrogen in *Miscanthus*

Here there is a significant effect of storage method

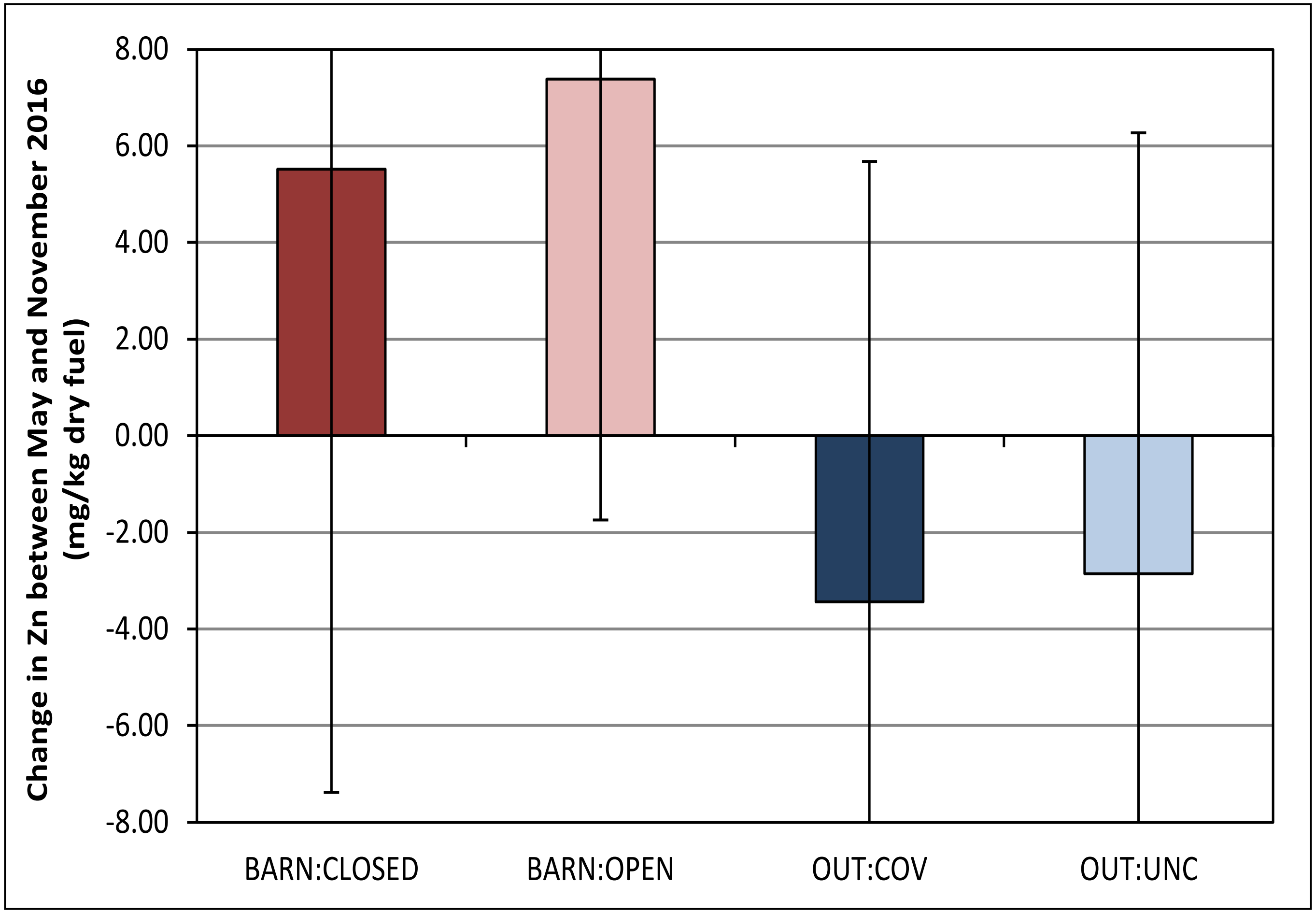


Here there is a significant effect of storage method



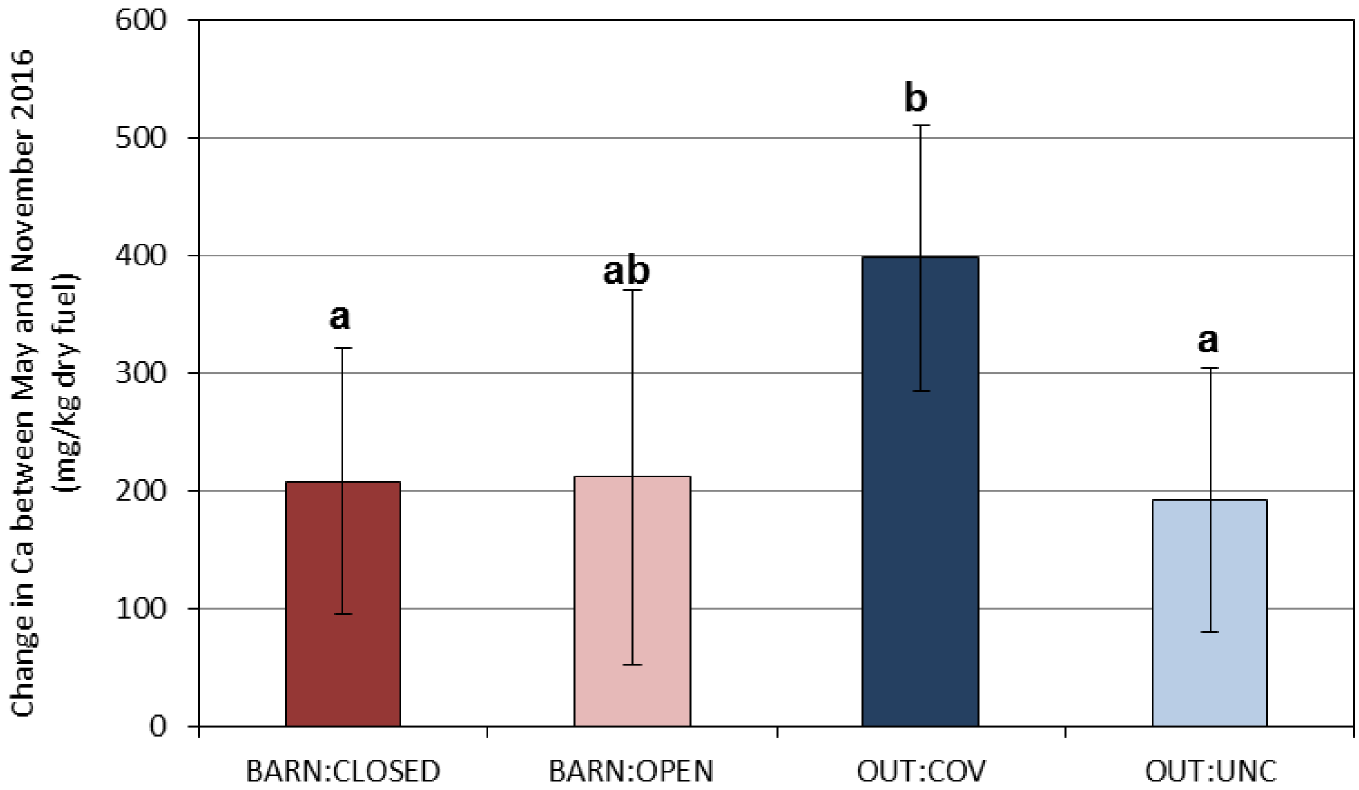
Zinc in *Miscanthus*

Here there is a significant effect of storage method



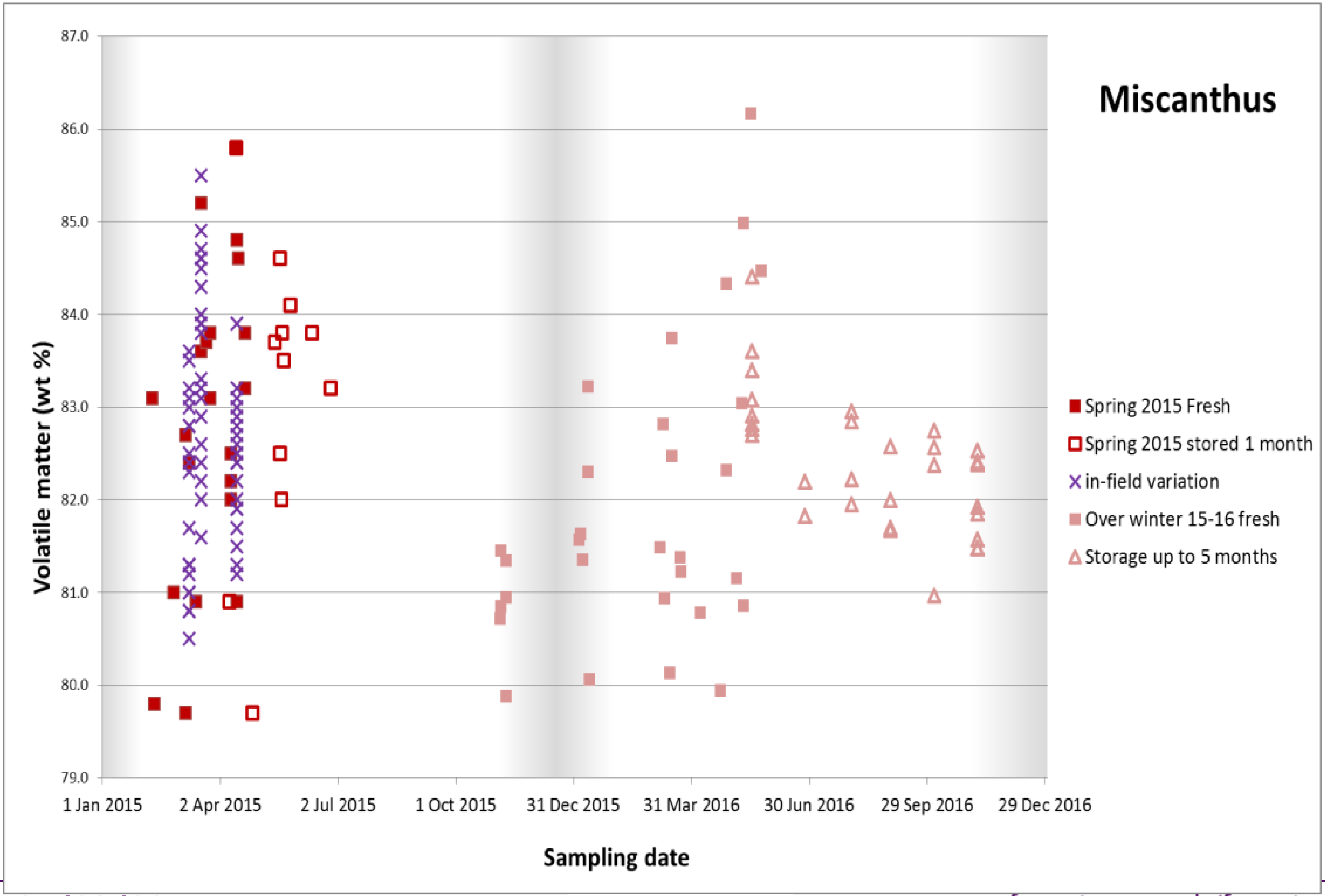
Calcium in *Miscanthus*

Here there is a significant effect of storage method



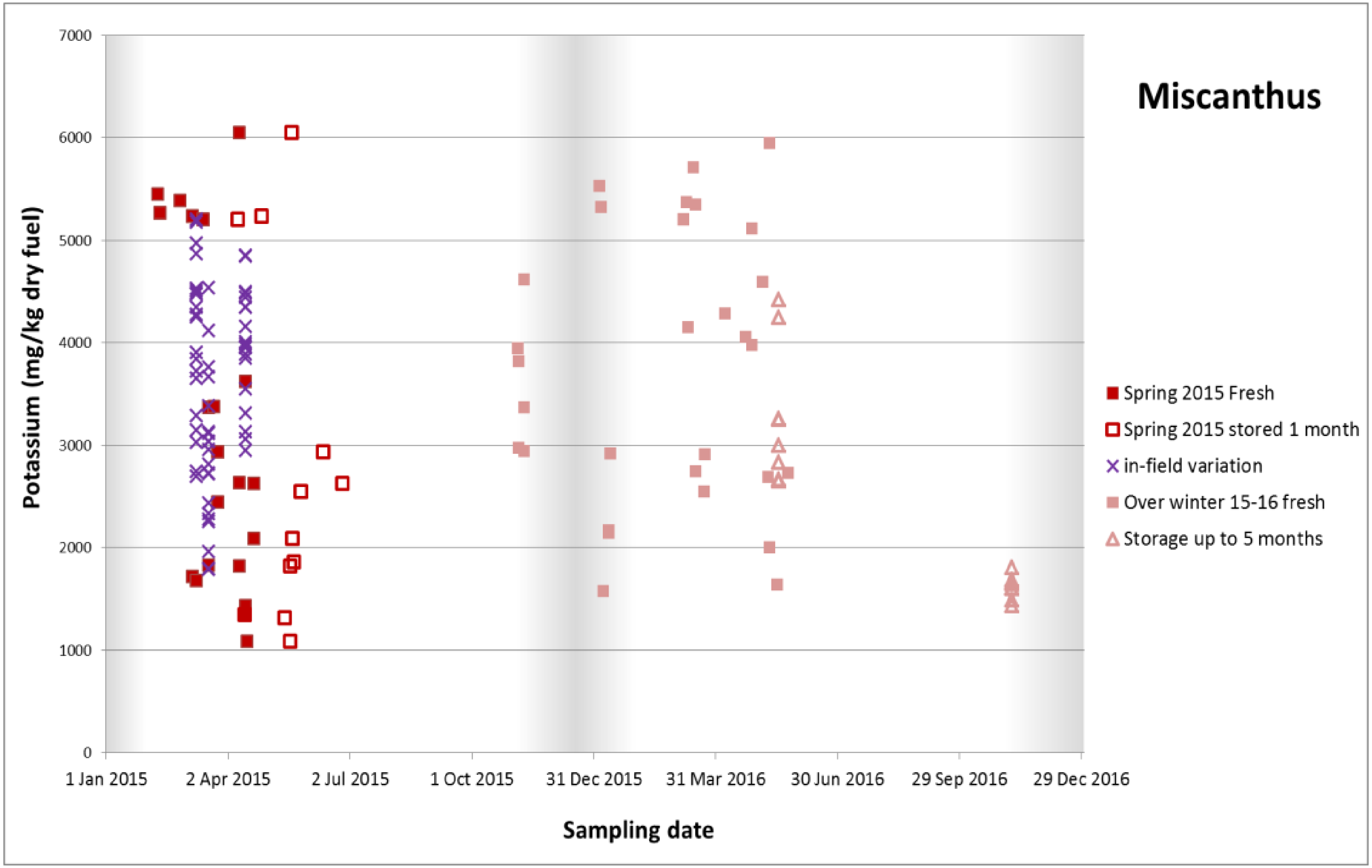
Volatile matter in *Miscanthus*

No effect of storage method but a decrease with storage



Potassium in *Miscanthus*

No effect of storage <u>method</u> but a decrease with storage



Hypothesis 7

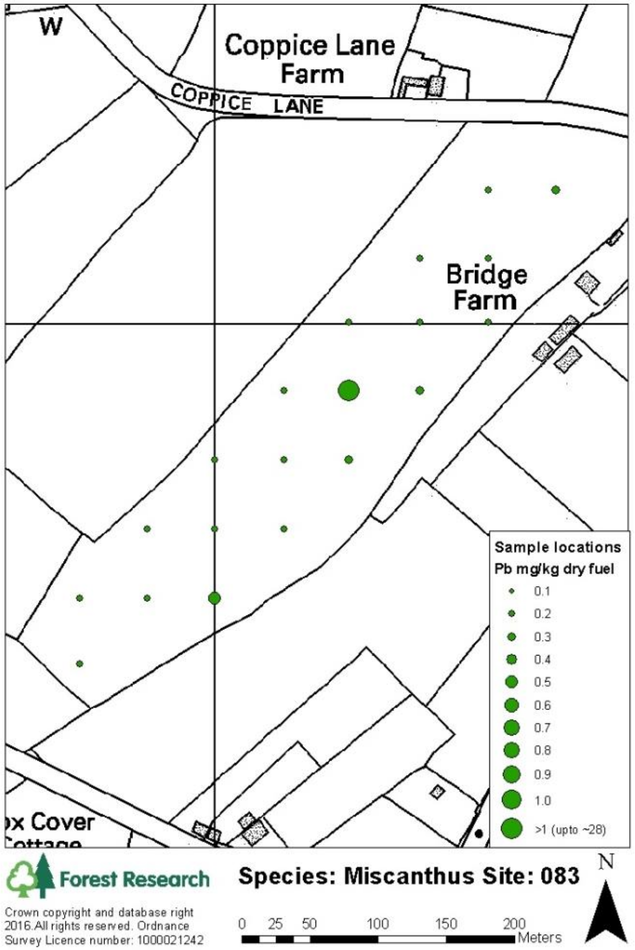
Within a given field, feedstock properties will be relatively uniform.

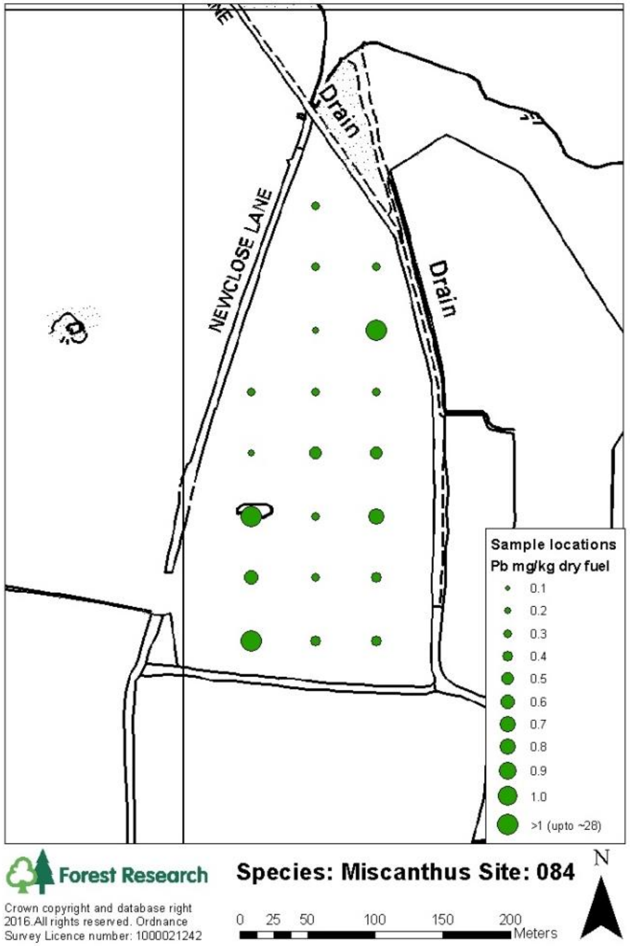
This hypothesis was investigated for *Miscanthus* and willow SRC. For some feedstock characteristics, the variation within fields was much greater than that between different sites. Similar behaviour between the two feedstocks was seen for a number of individual fuel quality parameters.

Variation between and within fields

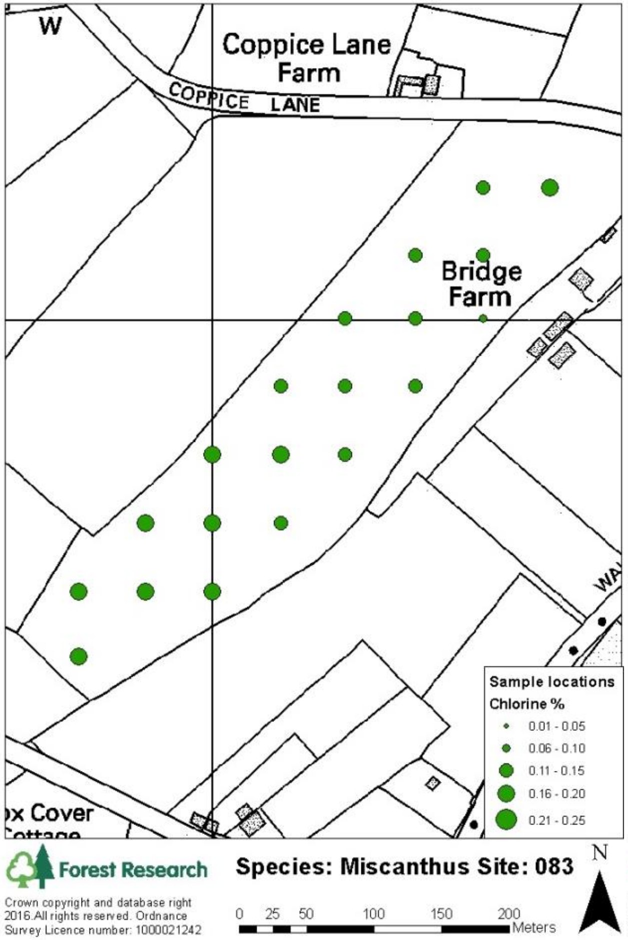
Variable	Variance between sites relative to total variance (%)	Variance within sites relative to total variance (%)
Moisture (ar)	92.16	7.84
Net calorific value (ar)	91.98	8.02
Ash content (d)	38.17	61.83
Volatile matter (daf)	42.23	57.77
Gross calorific value (daf)	20.13	79.87
Nitrogen (daf)	64.63	35.37
Sulphur (daf)	10.53	89.47
Chlorine (daf)	73.57	26.43
Barium (d)	96.14	3.86
Chromium (d)	5.57	94.43
Copper (d)	5.1	94.9
Nickel (d)	0.65	99.35
Zinc (d)	87.69	12.31
Arsenic (d)	1.5	98.5
Mercury (d)	0	100
Cadmium (d)	74.81	25.19
Lead (d)	0	100

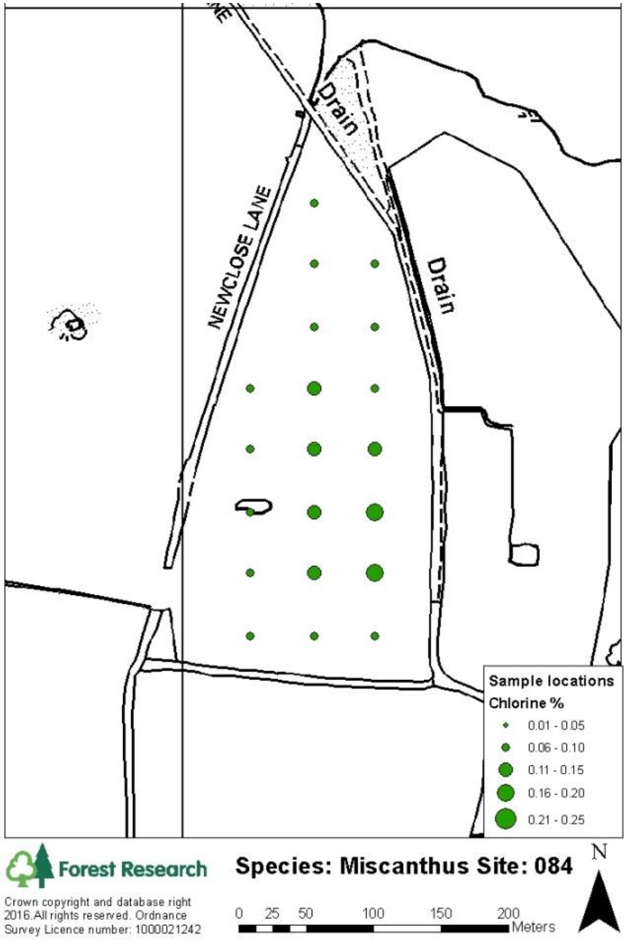
Variation in lead between and within fields





Variation in chlorine between and within fields





Hypothesis 10

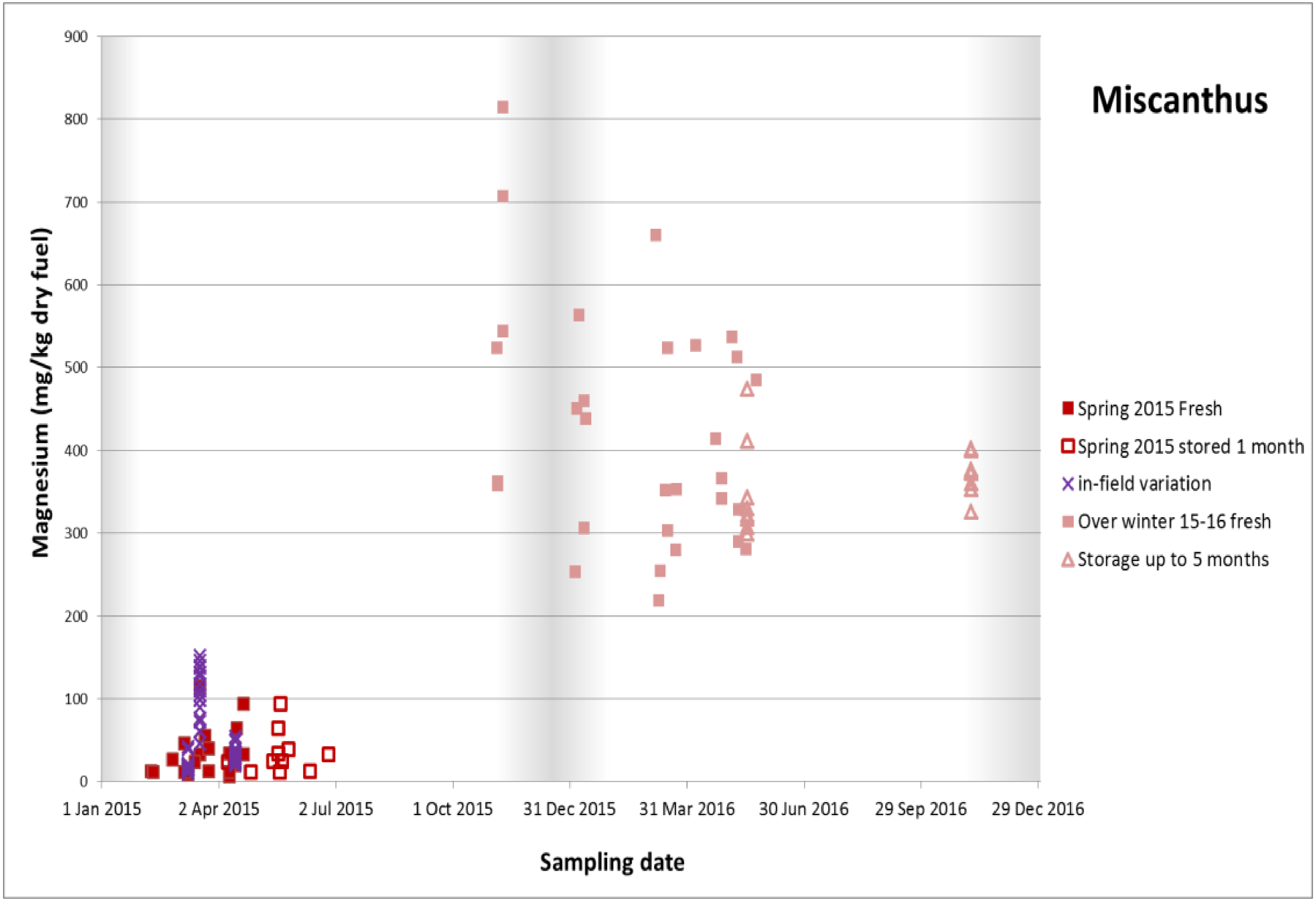
The feedstock characteristics of Miscanthus will differ from one year to the next at a given site.

The levels of many feedstock characteristics were broadly similar from one year to another but this was not the case for all parameters; some important properties differed, e.g. gross calorific value, magnesium and phosphorus

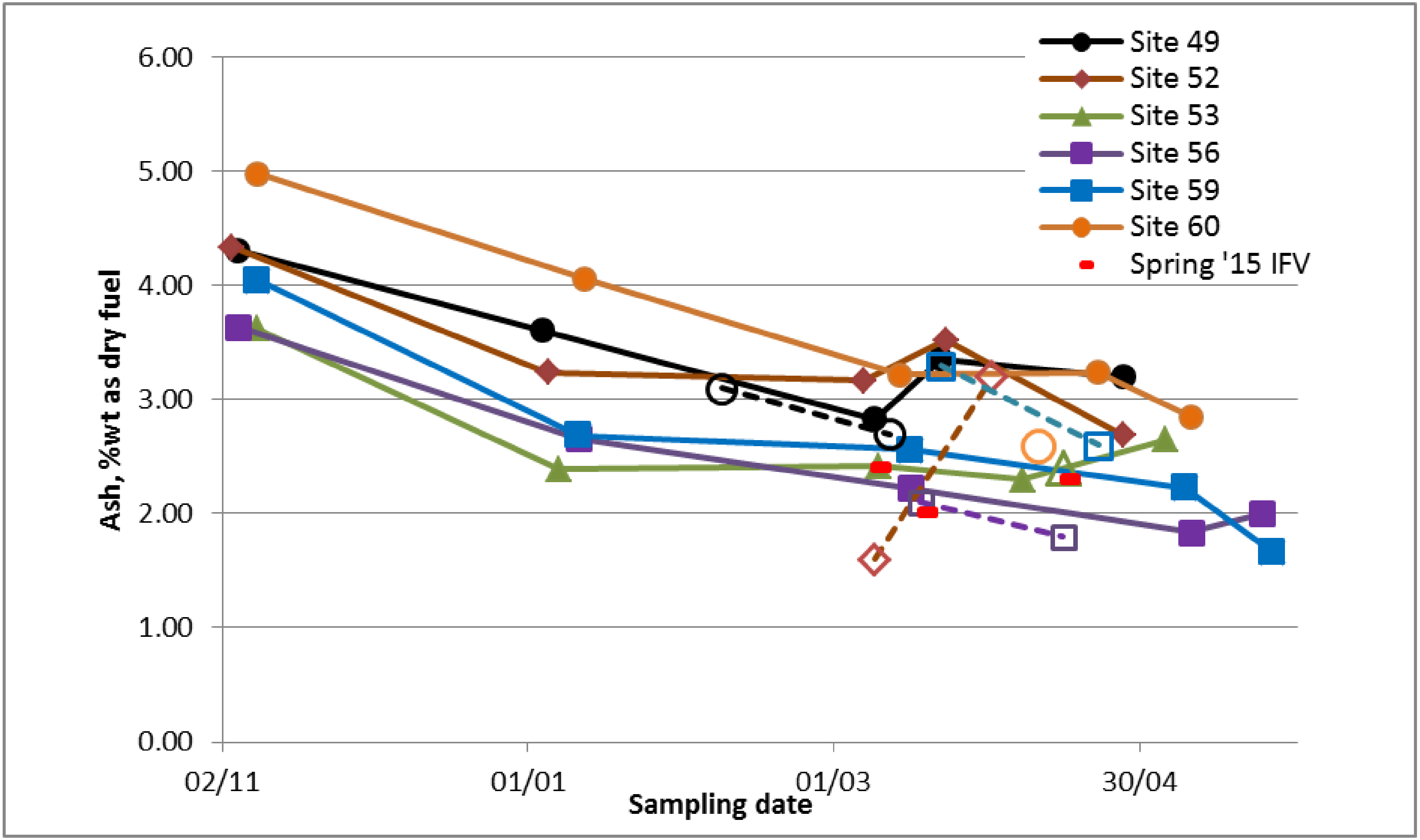
Some parameters had broadly similar dynamics even though the absolute levels were slightly different, e.g. moisture content, net calorific value, ash, and chlorine

Nitrogen levels were broadly similar in the seasonal changes in the two years but for a given time of year the direction of change differed

Magnesium in *Miscanthus*



Ash in *Miscanthus*



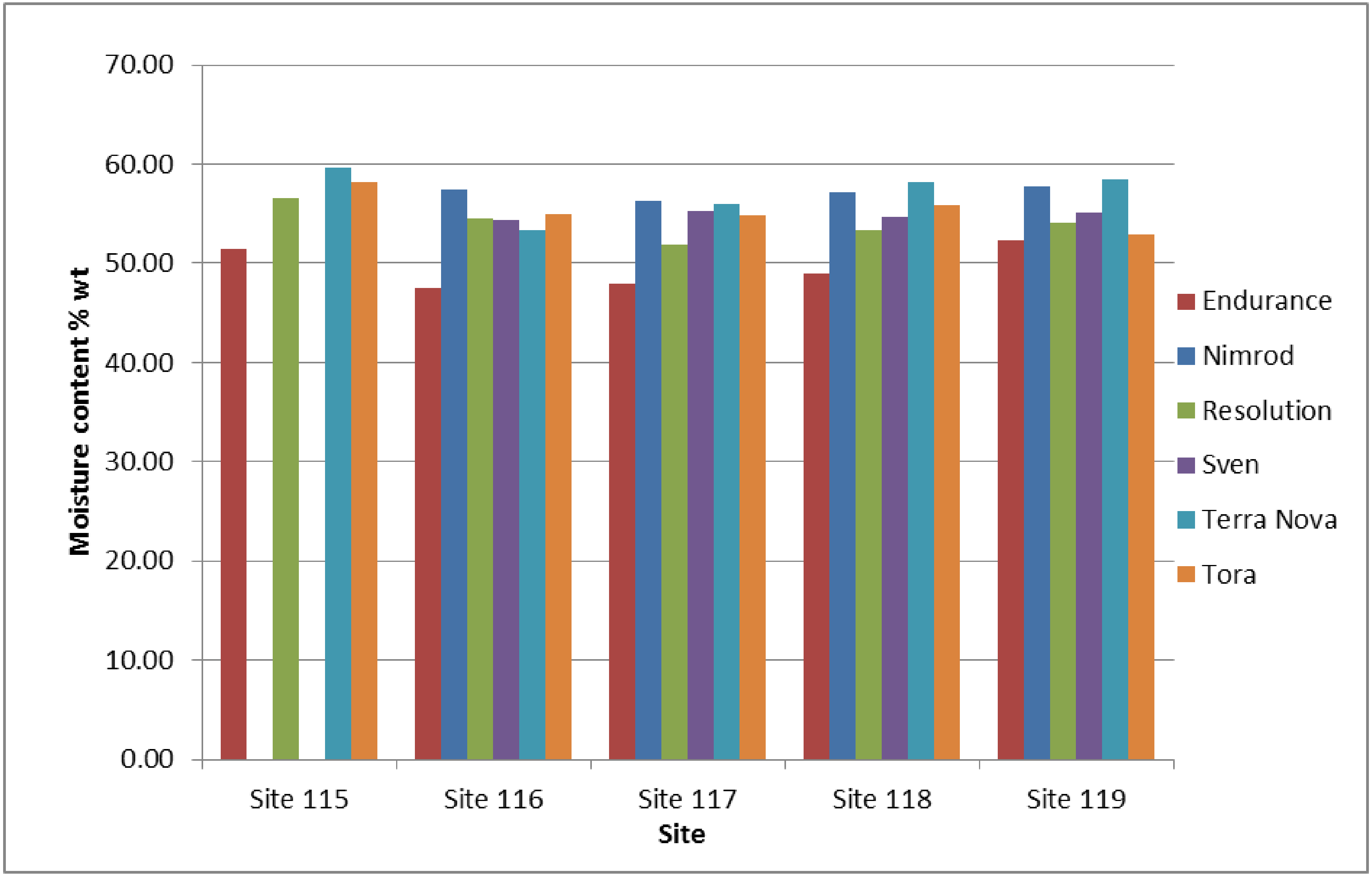
Hypothesis 11

The feedstock characteristics of willow SRC varieties will differ from one variety to another in a consistent manner from one location to another.

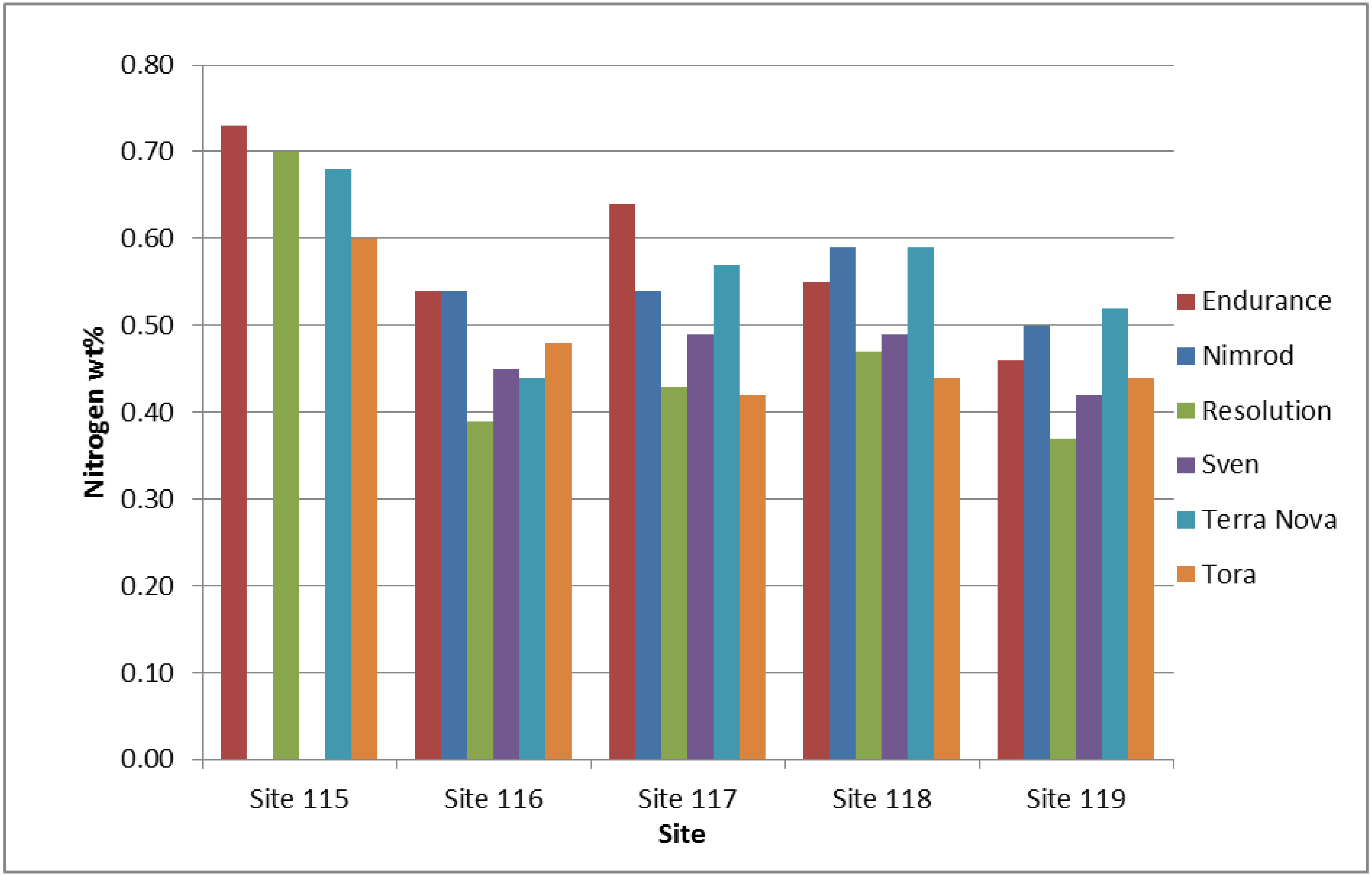
Approximately 40% of the parameters analysed had statistically consistent rankings; considering the results as a whole no variety combined the best ranking in all parameters.

For the majority of parameters however, there was not a consistent ranking

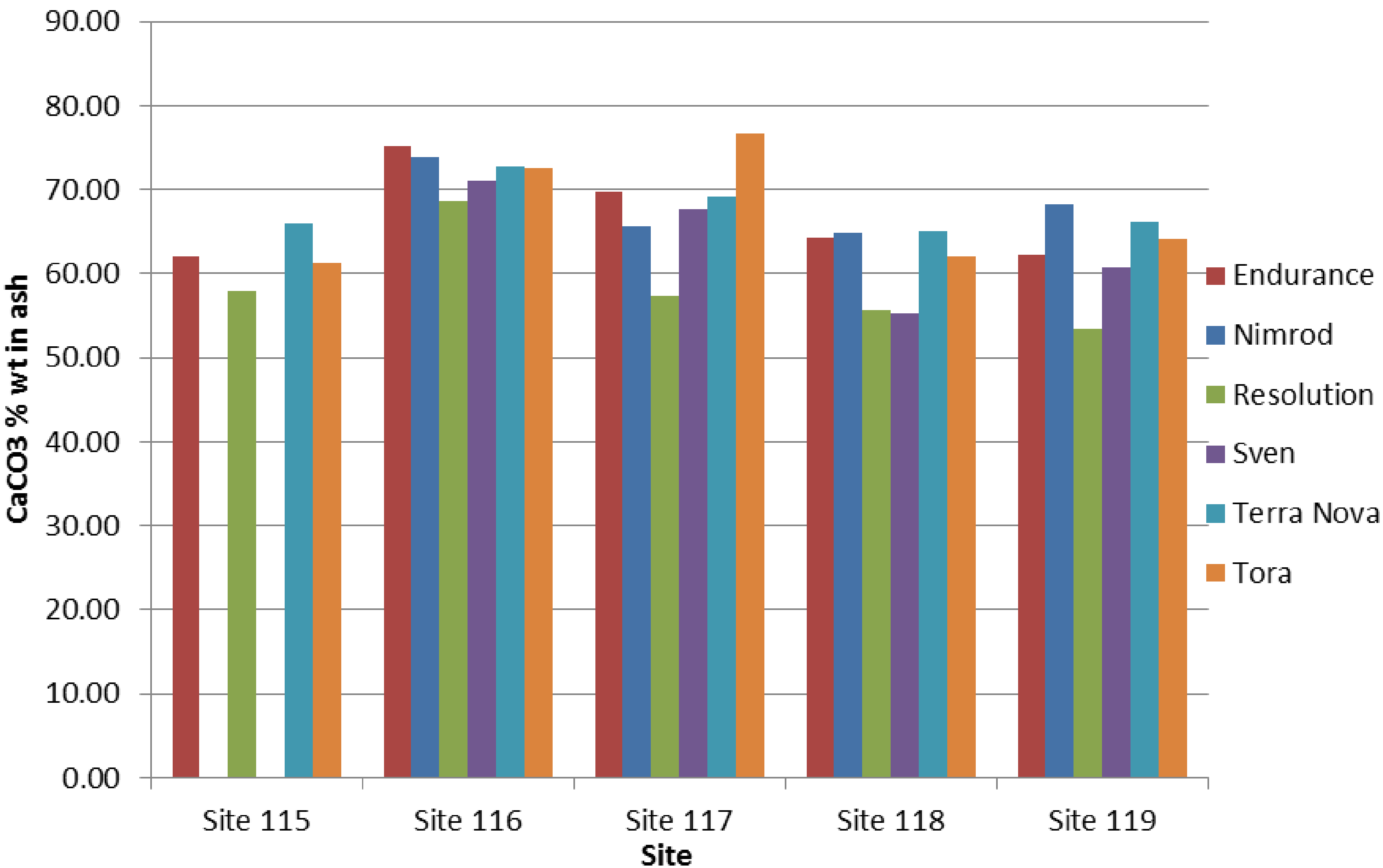
Moisture in willow SRC varieties



Nitrogen in willow SRC varieties



CaCO3 in willow SRC varieties



Hypothesis 8

The process of pelletisation will influence the fuel properties and/or composition.

There was a marked change in physical properties and chemical composition of *Miscanthus* following pelletisation. There was a relatively high risk of product contamination, either from deliberate use of additives, from other materials or wear products from the grinding process or the pellet mill itself.

Due to the limited number of samples no clear conclusions could be drawn on changes to the chemical compositional aspects which were not directly related to the additives used by the pellet producer.

Steve???

Implications for growers

- Species choice is likely to be determined by the farm's capability, expected yields and personal preferences rather than a consideration of fuel characteristics. Species differences are however highly relevant to anyone sourcing feedstocks
- Growers' experience of local weather may be a useful guide to likely feedstock properties but the long term average seems to be of limited value in predicting crop quality.

Implications for growers

- Willow growers: leaves should generally be excluded by harvesting in winter, if soil conditions allow.
- Poplar growers may improve the quality of harvested tops by winter harvesting but if the crop is harvested in the summer, quality of tops could be improved by storing until the leaves have been shed.
- Conifer SRF tops usually had higher levels of most elements than the stem wood and bark, but the levels tended to be so low that even tops could be harvested without exceeding quality thresholds. Quality of harvested tops can be improved by storing them so that needles have fallen off.

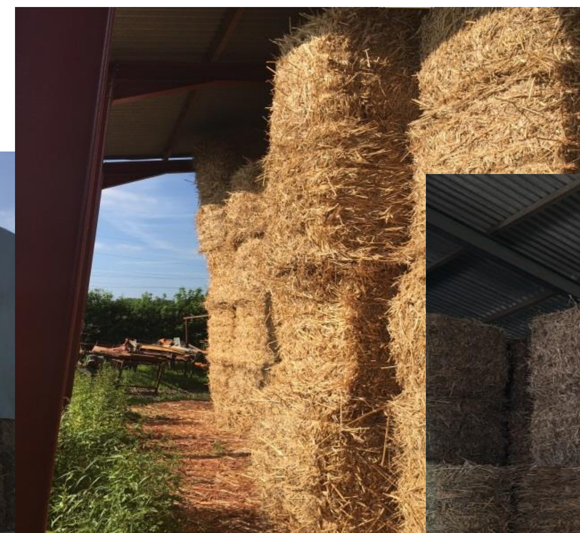
Implications for growers

- Willow SRC: harvesting times should be limited to after leaf fall through to bud burst and considerable flexibility within this period
- In cases where there were significant changes during storage of *Miscanthus* bales, the majority decreased fuel quality.
- Where storage method of *Miscanthus* bales was significant, no single method is likely to minimise the deterioration in all aspects of feedstock quality

Implications for growers

- There were major changes in many aspects of *Miscanthus* quality during storage. Storage method and duration could also be influential - these findings should be considered carefully by the sector and a wider range of sites and storage duration may be worthy of further investigation.






Implications for growers

- Only limited statistical analysis of crop management practices was possible, but
  - this identified possible relationships between year of planting and both cadmium in *Miscanthus* and sodium in willow SRC.
  - the age of sampled material appeared to influence several characteristics in both willow SRC and spruce SRF bark,
  - planting density had impacts on levels of barium in spruce SRF stem wood as well as the volatile matter, nitrogen, copper and cadmium in spruce SRF tops.
- Although these are interesting insights, the evidence is not sufficiently robust to make recommendations to growers and further investigation would be necessary if any of these feedstock properties was thought to be important.

Key influences on quality

- For growers of *Miscanthus,* poplar SRF and spruce SRF, the key influences on many properties, i.e. season and storage, can be manipulated.
- Willow SRC growers have a reasonable degree of control over some of the important feedstock characteristics by their choice of variety, harvesting time – as a means of controlling leaf content– the age of the root stock and the length of the cutting cycle.
- For poplar SRF and spruce SRF, many properties can be adjusted by choice of plant part to market, and harvest time. Feedstock properties were relatively insensitive to the way spruce SRF was grown.

Quality and quantity

Feedstock quality must be considered in tandem with biomass yields. Although the seasonal changes in quality we observed between autumn and spring would generally be beneficial, we did not collect yield information so it is not possible to estimate the overall impact of crop quality and quantity from our project.

This is less of an issue for willow SRC, poplar SRF and conifer SRF growers because seasonal changes in biomass yield are less pronounced.

If there is a price advantage for feedstock quality, the woody crops could be managed to optimise quality with little counter impact on quantity.

Comparison of feedstocks

Feedstock	Ash %wt (d)	Chlorine % (DAF)	Alkali index* ($kg(Na_2O+K_2O)/GJ$)
Miscanthus	2.3	0.14	0.204
Willow SRC	1.8	0.02	0.147
Willow SRC – Leaves	8.0	0.16	0.706
Poplar SRC	3.0	0.01	0.171
Poplar SRF – Trunk (including bark)	1.6	0.01	0.112
Poplar SRF – Tops	4.5	0.03	0.340
Poplar SRF – Leaves	9.1	0.09	0.871
Spruce SRF - Trunk	0.4	0.01	0.038
Spruce SRF – Tops	2.4	0.04	0.195
Spruce SRF - Bark	2.3	0.04	0.158

Comparison with wood pellet standards

Property Class	Reference standard	A1	I3	*Miscanthus*		Willow SRC		Poplar SRF		Conifer SRF	
Origin/source (permitted feedstocks)	ISO 17225-1	Stemwood Chemically untreated wood residues.	Forest, plantation, virgin wood. By-products and residues from wood processing industry. Chemically untreated wood residues.	A1	I3	A1	I3	A1	I3	A1	I3
Moisture, %wt. (ar)	ISO 18134	≤10	≤10								
Ash, %wt. (d)	ISO 18122	≤0.7	≤3.0		Large seasonal effect		Stems		Stems	Stem wood	
Net CV, kJ/kg (ar)	ISO 18125	≥16,500	≥16,500								
Nitrogen %wt. (d)	ISO 16948	≤0.3	≤0.6					Stems	Stems	Stem wood	Stem wood; bark
Sulphur %wt. (d)	ISO 16994	≤0.04	≤0.05			Stems	Stems	Stems; tops with no leaves	Stems; tops with no leaves		Stem wood; bark
Chlorine %wt. (d)	ISO 16994	≤0.02	≤0.1				Stems	Stems	Stems;	Stem wood	
Arsenic mg/kg (d)	ISO 16968	≤1	≤2								
Cadmium mg/kg (d)	ISO 16968	≤0.5	≤1					Stems	Stems		
Chromium mg/kg (d)	ISO 16968	≤10	≤15								
Copper mg/kg (d)	ISO 16968	≤10	≤20					Stems; tops with no leaves			
Lead mg/kg (d)	ISO 16968	≤10	≤20								
Mercury mg/kg (d)	ISO 16968	≤0.1	≤0.1								
Nickel mg/kg (d)	ISO 16968	≤10	-		-	Stems	-	Stems; tops	-		-
Zinc mg/kg (d)	ISO 16968	≤100	≤200				Stems	Stems; tops with no leaves			

Implications for end-users

For all conversion technologies, proper matching of the fuel and equipment is important. Different conversion technologies will have different acceptable levels for each feedstock parameter. These limits will depend on a number of factors, such as steam parameters, grate design and technology type and will tend to be more restrictive for those technologies offering the highest quality outputs (e.g. highest efficiency or specific conversion products). For all feedstocks, the implications for buyers are that consideration must be given to the feedstock characteristics of prime importance in a particular application.

S, N and Cl

Levels of sulphur and nitrogen were low when compared to typical UK coal values, although nitrogen in particular was elevated in the leaves.

Chlorine contents were heavily dependent on the feedstock, with *Miscanthus* containing some of the highest levels, together with the poplar and willow leaves.

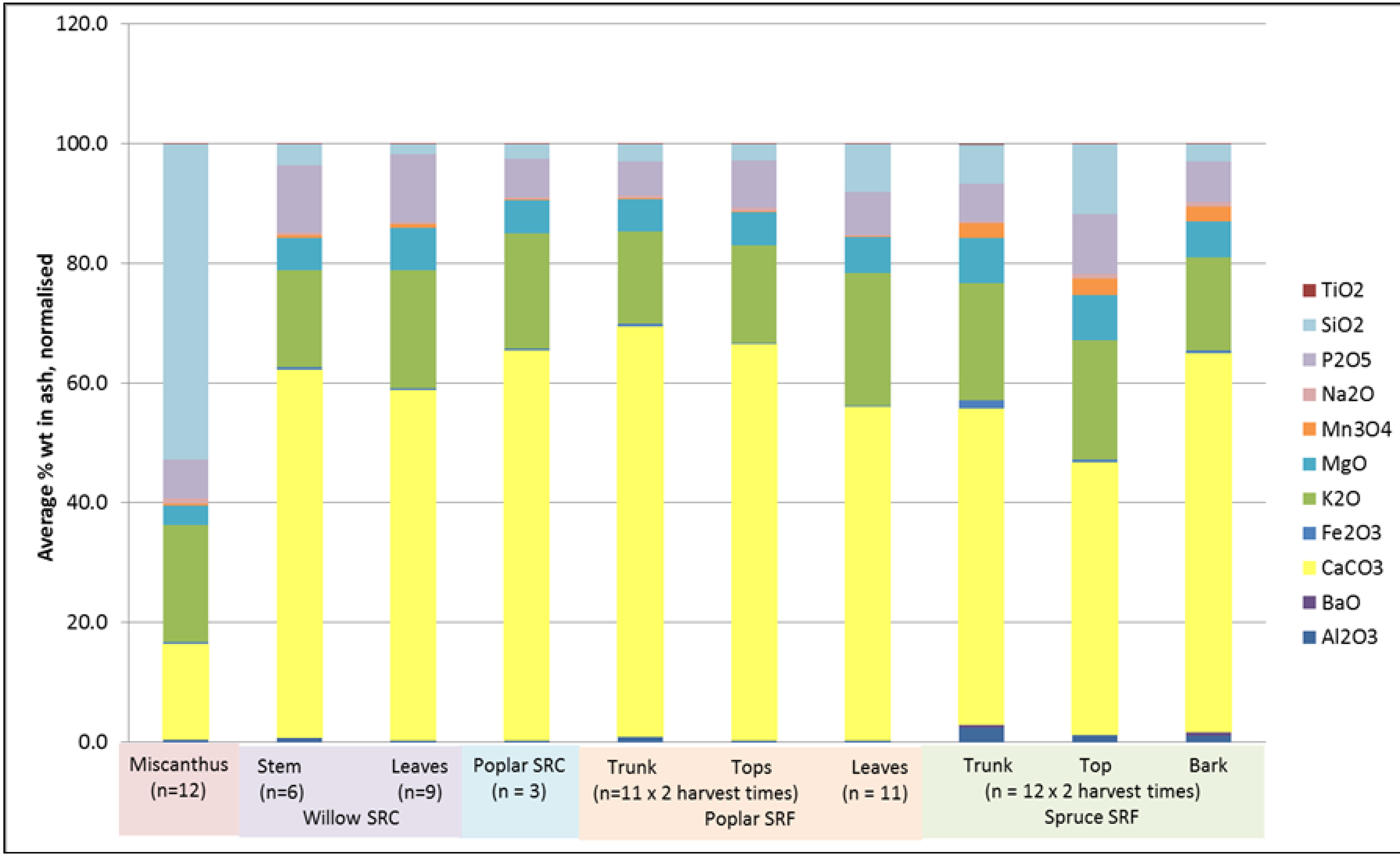
Buyers should therefore check the levels of leaf material in willow and poplar and consider specifying a harvesting window or, in the case of poplar tops harvested during the growing season, the use of a storage period to ensure that leaf material is shed.

Ash and ash composition

Compared to most coals, the ash levels seen in the project feedstocks were low, with the SRF stems showing the lowest levels.

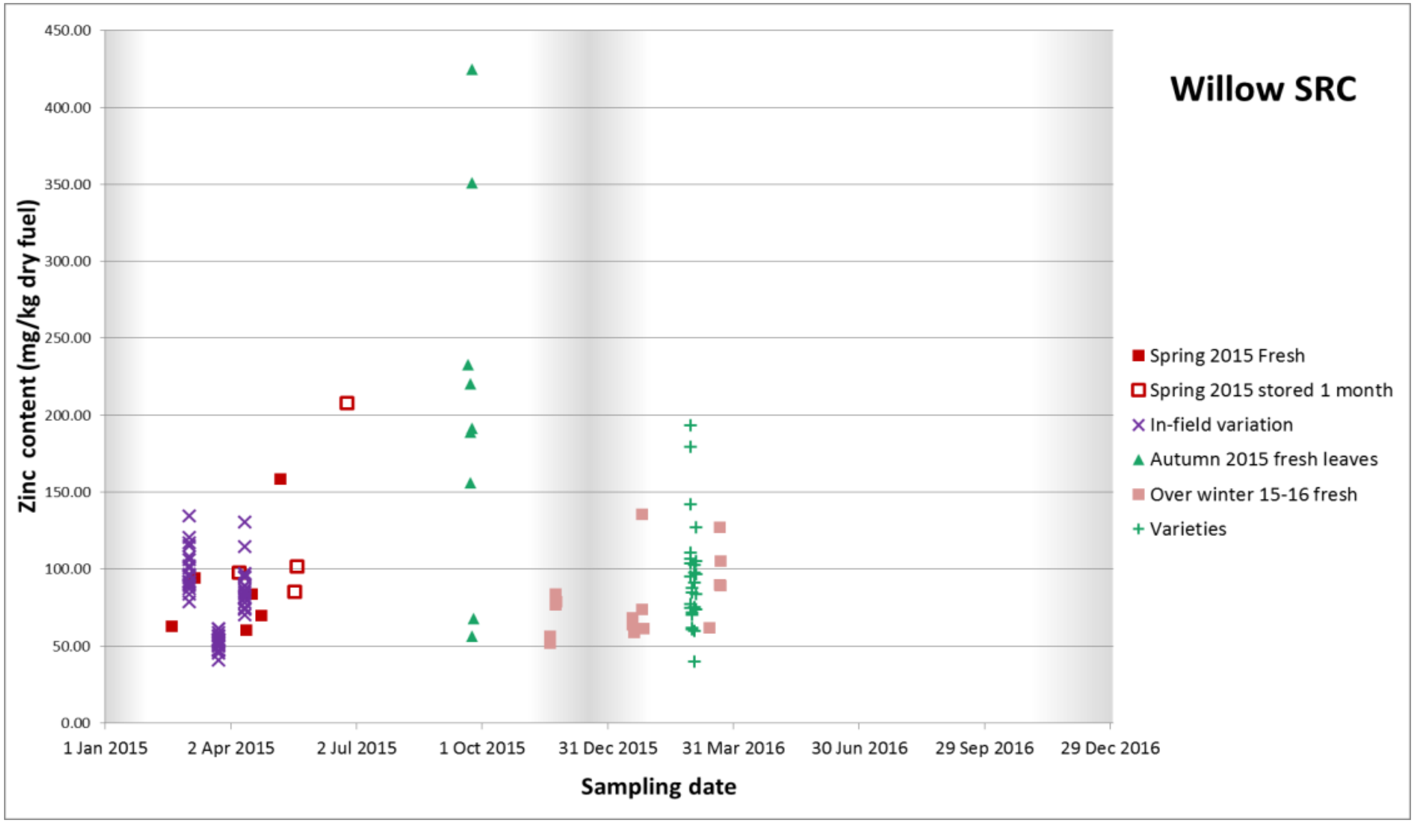
While coal ash is primarily alumino-silicate based, the ash from most of the biomass feedstocks was primarily composed of calcium and potassium compounds. The exception was *Miscanthus*, which contained significant levels of silica.

Ash composition



Trace metals

The feedstocks used in this project were generally so low in trace metals that this unlikely to be an issue. The possible exception was zinc in willow SRC stems.



The levels of ash, chlorine content and calculated alkali index for the *Miscanthus* samples were actually similar to the SRF conifer and poplar tops

By contrast, some of the *Miscanthus* pellets had elevated sodium levels (caused by addition of caustic soda to improve pellet throughput) which would have severe consequences for conversion plans in terms of corrosion and fouling.

This illustrates that common commercial practice can have a significant impact on fuel quality and that good communication between supplier and end-user is necessary to maintain fuel quality requirements.

Conclusions

This project provides a wealth of robust information and many consistent high-level findings to inform biomass growers and end-users. The findings have challenged some widely held views, reinforced others and hinted at some intriguing differences that may be worth further study.

It was not possible to derive simple guidance for biomass growers because of the differences in the behaviour of the individual feedstock characteristics. For any one year and site, the net effect of these changes is difficult to predict.

If there was sufficient premium for crop quality, a monitoring programme, which could focus on the most important parameters for the end-use in mind, could be considered.