MELiSSA

TN 85.1 85.3 85.4

Baseline data, preliminary cultivar selection, test performance and test result evaluation

prepared by/*préparé par*	UoGuelph Staff
reference/*réference*	Contract number 22070/08/NL/JC
issue/*édition*	1
revision/*révision*	1
date of issue/*date d'édition*	10/19/09
status/*état*	Final
Document type/*type dedocument*	Technical Note
Distribution/*distribution*	

Memorandum of Understanding 19071/05/NL/CP

CONFIDENTIAL DOCUMENT

APPROVAL

Title *titre*	TN 85.1 85.3 85.4: Baseline data, preliminary cultivar selection, test performance and test result evaluation	issue 1 *issue*	revision 1 *revision*

author *auteur*	UoGuelph Staff	date 10/19/09 *date*	

Reviewed by: Approved by:	date *date*

CHANGE LOG

reason for change / *raison du changement*	Issue/ *issue*	Revision/ *revision*	Date/*date*

CHANGE RECORD

Issue: 1 Revision: 1

reason for change/ *raison du changement*	page(s)/*page(s)*	paragraph(s)/ *paragraph(s)*

List Of Abbreviations

ALS	advanced life support
BLS	biological life support
CESRF	Controlled Environment Systems Research Facility
ESA	European Space Agency
HPC	Higher Plant Chamber
MELiSSA	Micro Ecological Life Support System Alternative
NCER	net carbon exchange rate
UAB	Universitat Autònoma de Barcelona
UoGuelph	University of Guelph

Table Of Contents

Table Of Figures

INDEX OF TABLES

Index of Tables

LIST OF APPENDICES

List of Appendices

1 Introduction

This document presents various elements of technical notes 85.1, 85.3, and 85.4 of the Phase A 'Characterization of Candidate Wheat Varieties' component of the HPC Integration into the MELiSSA Pilot Plant project.

Considerable advances have been made in the last few years at the CESRF in devising management strategies and control algorithms for crops grown in sealed environments. Specifically, the utility of Net Carbon Exchange Rate (NCER) analysis has been successfully demonstrated as a means to assess higher plant responses to a range of environment (control) variables at the full canopy scale. Particular emphasis has been placed on quantifying plant responses to atmospheric CO_2 concentration and light intensity, particularly with beet, lettuce and to a lesser extent kale and soybean. The NCER approach involves the determination of plant growth responses (biomass gain) through the direct measure of net sequestration of CO_2 in a hermetically sealed plant growth chamber. This is done by integrating metered compensatory injections of bottled CO_2 into the chamber in order to replace that taken up by the canopy through net photosynthesis. The CESRF has two chambers dedicated to simultaneous NCER analysis and crop production at the full canopy scale. These chambers are designated as the SEC-2 chambers (Sealed Environment Chambers – x 2).

The NCER approach has been used to validate a canopy photosynthesis model outlined by Thornley. The model is based on incremental biomass partitioning to leaves, an increase in leaf area and, hence, effective photosynthetic area. Provision is made in the model for light attenuation within the dense canopy as Leaf Area Index (LAI) develops. The Thornley model has been validated using data collected from the SEC-2 chambers for beet and lettuce. The model has performed well, but calibration of the model tuned for staged (multiple age classes) culture is still required.

The principle of model development for the HPC is similar to other MELiSSA compartments although attention must also be duly paid to factors affecting partition of the plant biomass into edible and inedible fractions, nutrient uptake and evapo-transpiration. As part of our historical empirical production trials, including NCER analysis, we have

collected a considerable amount of baseline data relating to biomass partitioning, mineral composition, proximate (carbohydrate, protein, fat, ash) composition and nutrient uptake / depletion profiles from a hydroponics reservoir (using off line HPLC) for beet and lettuce. These data have been provided to MELiSSA partners (eg. UBP) for use in global simulation and stoichiometric modeling of the HPC.

The CESRF has, for a number of years, been involved in the collection of baseline data required for crop metabolic characterization. These include the computer logging of key environment variables (CO2 concentration, Light Intensity, Temperature, VPD, Pressure) and the regular monitoring of nutrient uptake in hydroponics (using off-line HPLC), evapo-transpiration and logistical (labour/replacement part) requirements. All of our studies include, at crop harvest, analysis of biomass and partitioning, leaf area, proximate composition, fibre content and mineral composition. All of these tissue data are now collected within internal UoGuelph laboratories.

2 Cultivar Selection

Collection of data for wheat, first involves the identification, proposal and selection of a cultivar suitable for inclusion in the MELiSSA MPP. Three suitable wheat cultivars were identified and proposed for empirical trials in the SEC-2 chambers. Variables of interest in the selection of cultivars included;

- Harvest Index (edible: inedible biomass ratios)
- Gas-exchange/Air revitalization capacity
- Nutritional quality
- Small stature
- Cultivar availability and extent of use in controlled environments or terrestrial agriculture
- Non-GMO
- Disease tolerance and resistance
- Lighting requirement (intensity, spectral requirement and photoperiod)
- Licensed for production in Ontario, Canada

Based on these parameters, the CESRF identified the German cultivars '606' and 'Sable' and a University of Guelph cultivar 'Norwell' as the candidates for empirical trials in the SEC-2 chambers and eventually in

the HPC1 prototype. These cultivars exhibit short stature, high photosynthetic potential, growth promotion through extended photo periods and are among the leading cultivars used in terrestrial agriculture in Ontario, Canada. All three cultivars are hard red spring wheat varieties.

Cultivar	TKW (g)	Height	Heading	Maturity	*Fusarium* Rating	General Properties
606	31.8	75	53	91	S	Excellent milling properties, small stature, and high tolerance to fusarium
Norwell	35.2	85	50	90	MR	High yield and threshability as well as strong straw that resists lodging
Sable	35.8	75	50	93	MS	Similar to Sable with strong straw and very high protien yields
TKW = 1000 kernel weight S = susceptible, MR = moderately resistant, MS = moderately susceptible						

Table 1: Review of selected cultivar properties

3 SEC-2 Higher Plant Chambers

The sealed environment chambers at CESRF (SEC-2) were used exclusively for the generation of baseline data for Phase A activity. The SEC-2 chambers are constructed primarily of relatively inert materials such as glass, Teflon® and stainless steel. This minimizes off-gassing into the sealed environment. Typically, leakage rates of the chambers ranges from 4 – 7% per day. Leakage rates are calculated from the depletion of CO_2 as a marker gas in an empty, sealed chamber, over time. The SEC specifications and capabilities are detailed below.

1. Dimensions:
   Volume = 29 m^3 (430 ft^3) (4.5 m x 2.8 m x 2.3 m) per chamber
   Plant Growing Area = 5 m^2 (54 ft^2) (2 m x 2.5 m) per chamber
2. Materials used:
   Stainless Steel 316 (walls, floor, valves, plumbing)
   Tempered Glass (roof)
   Teflon (tubing, gas expansion bladders)
   Polypropylene (tubing, valves)
   Heresite (oxidation barrier)
   Viton (O-rings, solenoid seats)
   Silicone sealant (DOW-Corning RTV 732)

3. Analyzers:
   LiCor LI6262 Gas Analyzer for CO_2/H_2O vapour
   CAI O_2 Gas analyzer (model 200)
   Dionex DX500 HPLC Ion Chromatograph (offline)
4. Lights:
   9 x 600 W High Pressure Sodium (HPS)
   6 x 400 W Metal Halide (MH)
   500 and 800 µmoles m^{-2} s^{-1} PAR mid canopy
5. Sensors:
   Hydroponics system
      1) Electrical Conductivity (one per chamber)
      2) pH metres (one per chamber)
      3) Flow switch (one per chamber)
   Chamber
      1) Aspirated Air Humidity sensors (2/chamber)
      2) Aspirated Air Temp. sensors (2/chamber)
      3) Root Zone Temp. sensors (4/chamber)
      4) LiCor Quantum Sensor (one per chamber)
6. Environment Control:
   Temperature (10 to 40 °C) $\pm$ 0.2 °C
   CO_2 Concentration (ambient to 3000 ppm) $\pm$ 10 ppm
   O_2 Concentration (ambient to 40 %)
   Relative Humidity (50% to 95%) $\pm$ 5%

Illustration 1: Wheat growing in SEC-2 chamber 1

Air Handling

In the SEC-2 chambers air was conditioned for temperature and humidity and was re-circulated inside the chambers. Externally supplied chilled water and hot water were circulated through sealed and "heresite" coated (baked oxidation barrier) heat exchange coils mounted in an internal plenum at the rear of each chamber.

Condensate from the chilled water coil was measured and returned to the hydroponics nutrient reservoir. Heresite coated fans and fan motors with silicone covered wiring were also mounted in the plenum and distribute the air through stainless steel ducts with baked enamel louvres. Modulated hot and chilled water valves effected temperature and dehumidification control of the aerial environment.

Nutrient Supply

The nutrient requirements for the plants were supplied in a hydroponics medium stored in a 200 L tank inside the chamber. The solution was pumped through polypropylene tubing to the head of sloped stainless steel troughs. Five 2.5 metre long troughs were used in each chamber. Gravity assisted the return of the solution to the internal reservoir. The condition of the solution with respect to pH and electrical conductivity was replaced with fresh solution at regular 5 day intervals (without breaking an atmospheric seal).

Volume and Pressure Control

Each SEC-2 chamber was fitted with ten 200 litre double sealed Teflon® liners (Now Technologies Inc., Minneapolis, MN) manifolded on a 50 mm diameter stainless steel tube which protruded through the rear wall of the chamber. This provided a total expansion volume potential of 2.0 m^3 or ±1.0 m^3. Given the 29 m^3 internal volume of the chamber, this represents about 7% or ±3.5% volume expansion/contraction in response to possible temperature fluctuations within the chambers. The total temperature range influencing gas volume in the chamber represented by this capacity is about 20 Kelvin degrees (±10 degrees).

4 Batch Wheat Mixed Cultivar Trials

Under this task set, the SEC-2 chambers were readied for a crop production trial using wheat in batch, mixed cultivar culture. A total of three replications were performed using an Randomized Complete Block Design (RCBD), with a total of 5 growing trays (called 'blocks') in each (serial) replication and each of the three candidate cultivars represented in each block. The data collected included:

- Standard seedling leaf area using a Li-COR 300C Leaf Area Meter collected on a sub-set of un-planted seedlings (15 – 20

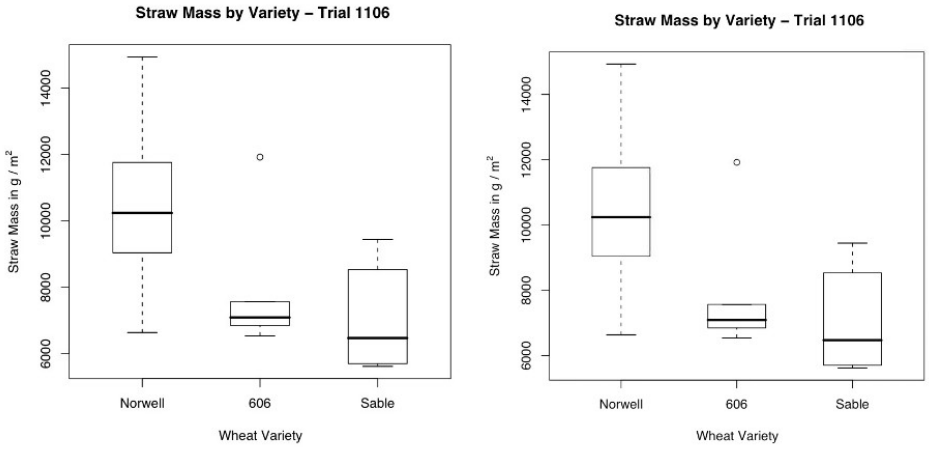
seedlings) sampled at start-up and planting of the crop in the SEC-2 chamber

- Profiles of chamber atmospheric temperature, humidity (VPD), light intensity and solution temperature over the duration of the period of closure
- Gas-exchange (CO2, O2), collected at six minute intervals by an Infrared-Gas Analyzer (IRGA) and Paramagnetic oxygen analyzer and logged by the HPC controller
- Nutrient and Water Uptake (NH^{4+}-N and NO^{3-}-N, NO^{2-}-N, $PO4^{3-}$, $SO4^{2-}$, Fl^{-}, Cl^{-}, Na^{+}, K^{+}, Ca^{2+}, Mg^{2+} and water) as determined from sampling of the hydroponics solution over its period of closure and off-line HPLC analysis. Water uptake is determined from changes in solution volume (± 2 L) at the time of solution replacement (5 day intervals) and nutrient uptake is measured over the same interval by difference of start and end concentrations corrected for water uptake (in triplicate)
- Edible biomass, nutrient content (carbon, nitrogen, phosphorus, potassium, calcium and magnesium) and proximate composition including proteins, lipids and carbohydrates
- Inedible biomass, nutrient content (carbon, nitrogen, phosphorus, potassium, calcium and magnesium), fibre (soluble and non-soluble), hemi-cellulose, cellulose and lignin.

Under this task set tissue samples were prepared and sent for analysis.

5 Results

In general, there were few notable differences between the three cultivars for the majority of the parameters analyzed.



Variety Effect - p = 0.03

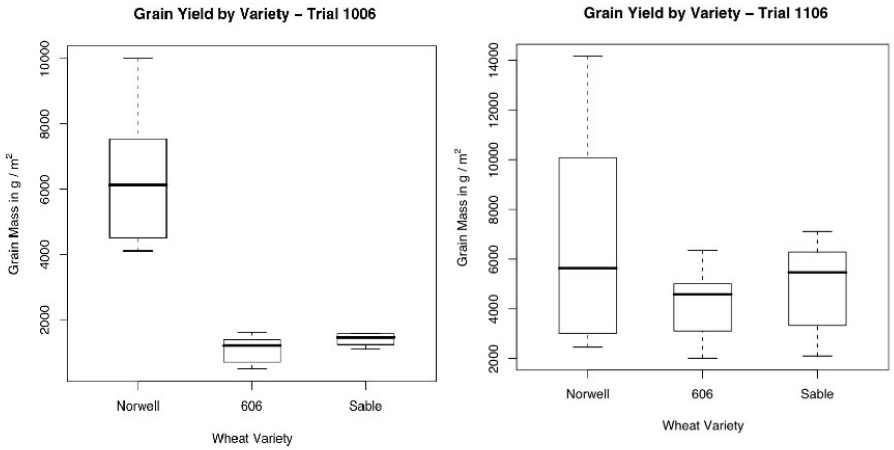
Tukey HSD

Variety Effect - p = 0.11

* No significant blocking effect in either trial

Illustration 2: Mixed culture straw yield

Straw yield was generally higher, yet statistically insignificant, with the Norwell cultivar.



Variety Effect - p = 0.002

Tukey HSD

Variety Effect - p = 0.37

* No significant blocking effect in either trial

Illustration 3: Mixed culture total yield

In mixed culture, total yield of Norwell was higher in one trial and equal to 606 and Sable in the second trial. Variability in yield was higher in the second trial.

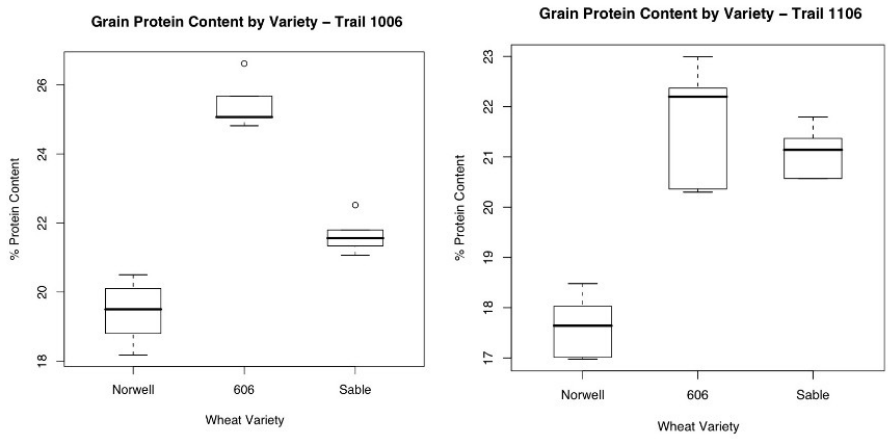


Illustration 4: Mixed culture protein content

Protein content was lower in Norwell than in 606 or Sable in both mixed batch production trials.

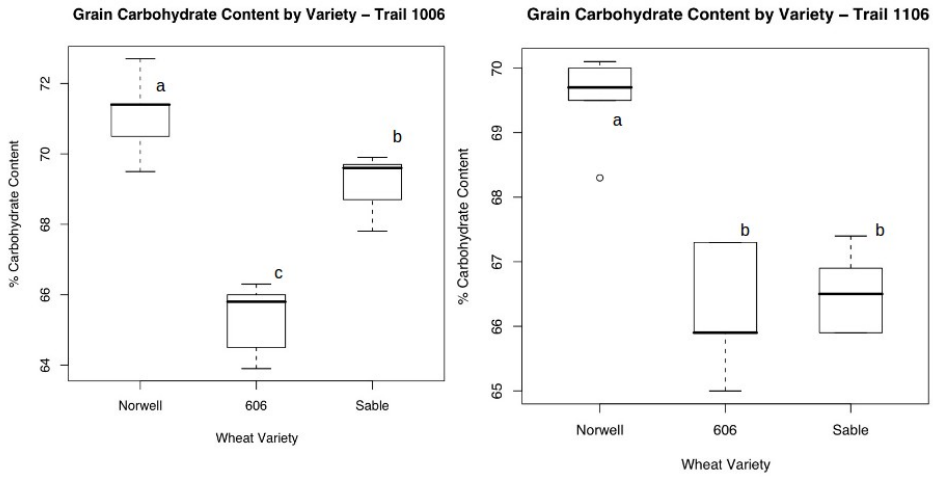


Illustration 5: Mixed culture carbohydrate content

Total grain carbohydrate content was generally higher in Norwell than in either 606 or Sable.

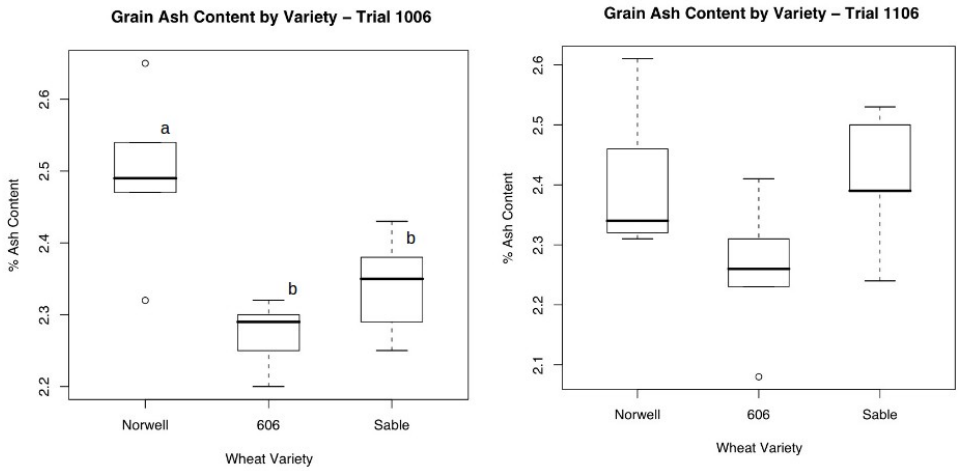


Illustration 6: Mixed culture ash content

Ash (mineral content) levels in the first trial were higher in Norwell but all three cultivars showed similar content in the second trial.

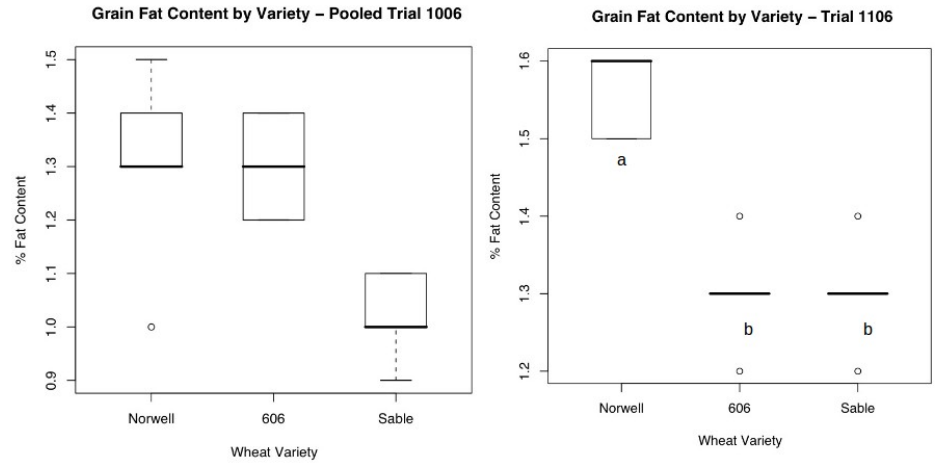


Illustration 7: Mixed culture grain fat content

Grain fat content was higher in 606 and Norwell in the first trial but only higher in Norwell in the second.

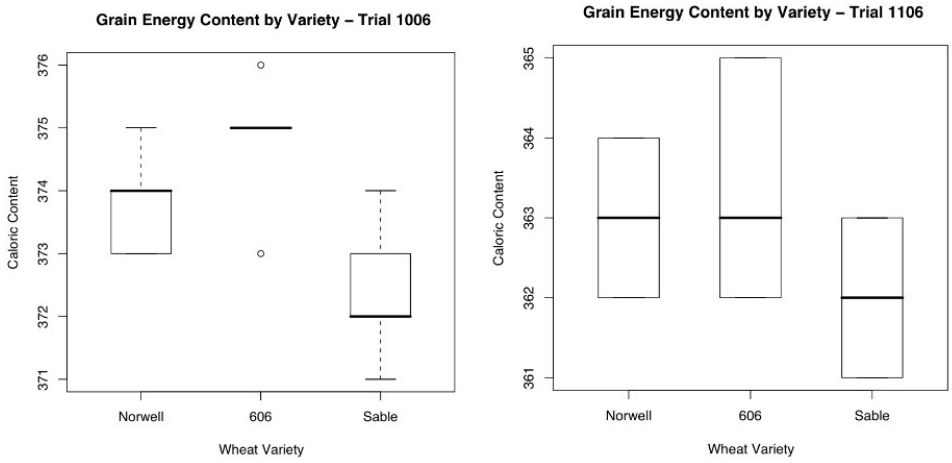


Illustration 8: Mixed culture grain energy content

There was no significant difference in caloric content between the three cultivars in either trial.

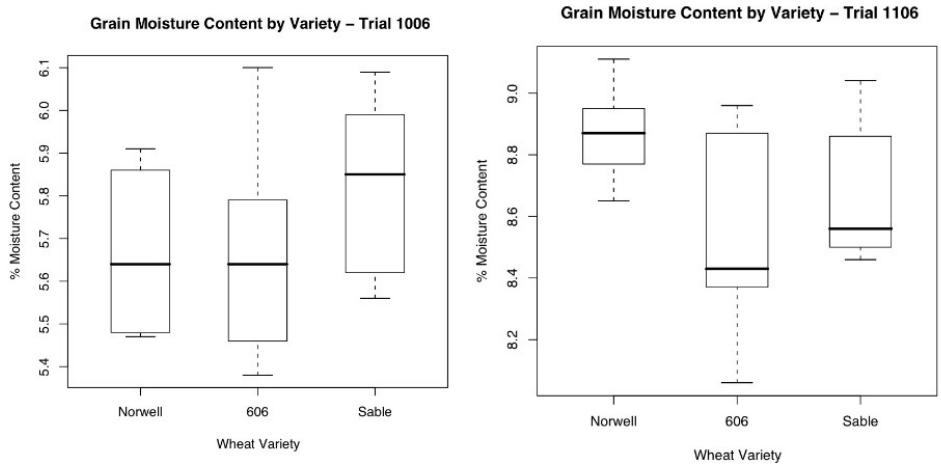


Illustration 9: Mixed culture moisture content

Similarly, there was no difference in moisture content between the wheat cultivars.

Overall the differences between the cultivars were inconclusive. Production of the cultivars in batch monoculture helped to quantify observed similarities and differences between 606, Norwell, and Sable.

6 Batch Wheat Cultivar Trials

Under this task set, the SEC-2 chambers were readied for a batch crop production trials for each of the three wheat cultivars. In these trials all 5 growing trays were filled with the same cultivar. The experiment was repeated, once for each of the three candidate cultivars. The data collected on the batch harvest included:

- Standard seedling leaf area using a Li-COR 300C Leaf Area Meter collected on a sub-set of un-planted seedlings (15 – 20 seedlings) sampled at start-up and planting of the crop in the SEC-2 chamber
- Profiles of chamber atmospheric temperature, humidity (VPD), light intensity and solution temperature over the duration of the period of closure
- Gas-exchange (CO2, O2), collected at six minute intervals by an Infrared-Gas Analyzer (IRGA) and Paramagnetic oxygen analyzer and logged by the HPC controller
- Nutrient and Water Uptake (NH^{4+}-N and NO^{3-}-N, NO^{2-}-N, $PO4^{3-}$, $SO4^{2-}$, Fl^{-}, Cl^{-}, Na^{+}, K^{+}, Ca^{2+}, Mg^{2+} and water) as determined from sampling of the hydroponics solution over its period of closure and off-line HPLC analysis. Water uptake is determined from changes in solution volume (± 2 L) at the time of solution replacement (5 day intervals) and nutrient uptake is measured over the same interval by difference of start and end concentrations corrected for water uptake (in triplicate)
- Edible biomass, nutrient content (carbon, nitrogen, phosphorus, potassium, calcium and magnesium) and proximate composition including proteins, lipids and carbohydrates,
- Inedible biomass, nutrient content (carbon, nitrogen, phosphorus, potassium, calcium and magnesium), fibre (soluble and non-soluble), hemi-cellulose, cellulose and lignin.

Chamber performance data includes data on chamber leakage and environmental control quality.

7 Results

Similar to mixed culture of wheat, batch culture resulted in subtle differences between the different cultivars, however a suitable candidate could still be ascertained.

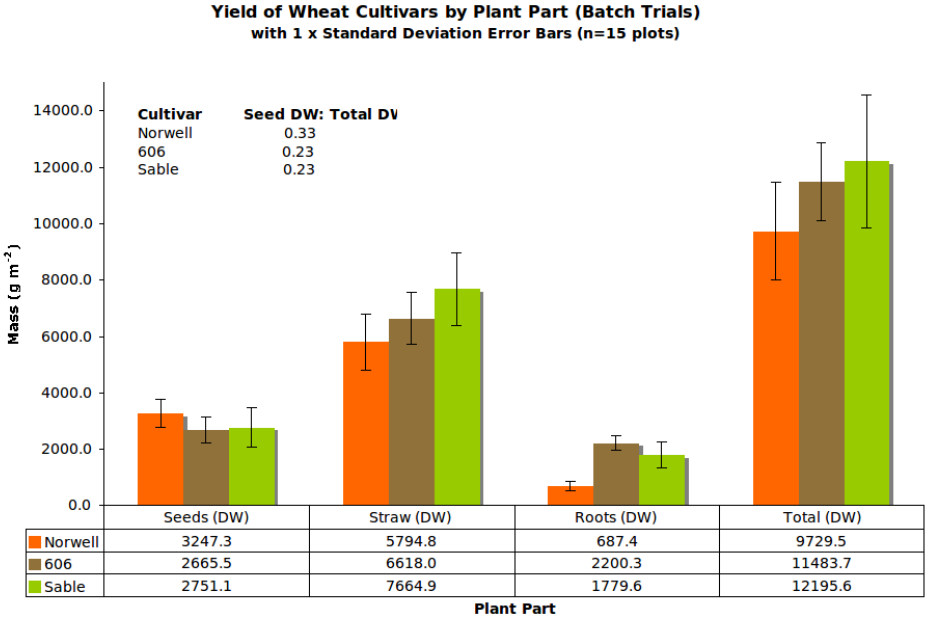


Illustration 10: Batch culture wheat yield by plant part

Norwell in batch culture produced the highest harvest index of the three cultivars tested. Additionally, Norwell had the lowest root dry mass while seed, straw, and total dry weights showed little difference.

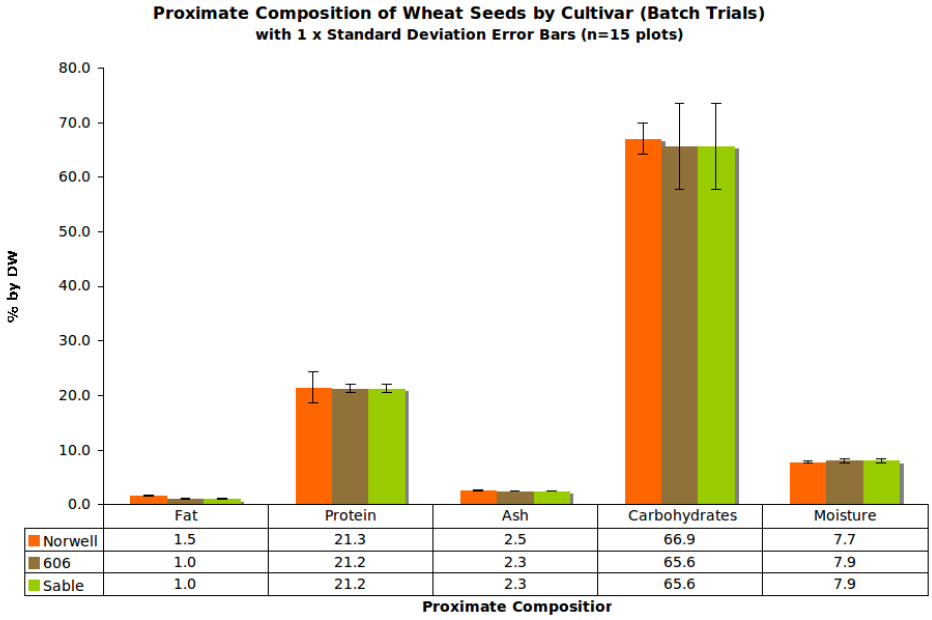


Illustration 11: Batch culture results of proximate analysis

Total fat, protein, ash, carbohydrates, and moisture showed no significant differences between Norwell, 606, and Sable.

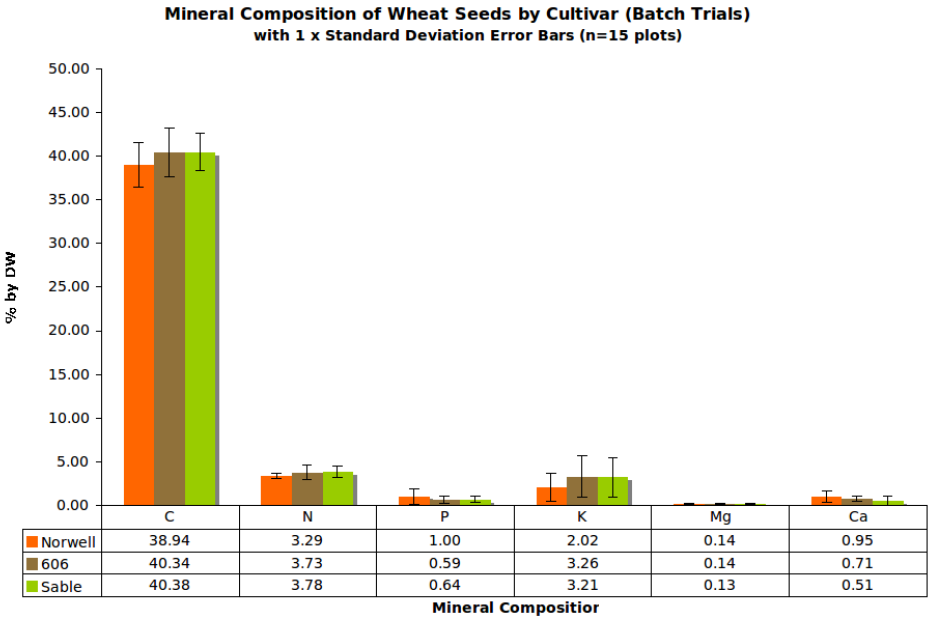


Illustration 12: Batch culture mineral composition of wheat kernels

As with proximate analysis, mineral analysis demonstrated no significant differences between total carbon, nitrogen, phosphorus, potassium, magnesium, or calcium between the three cultivars tested.

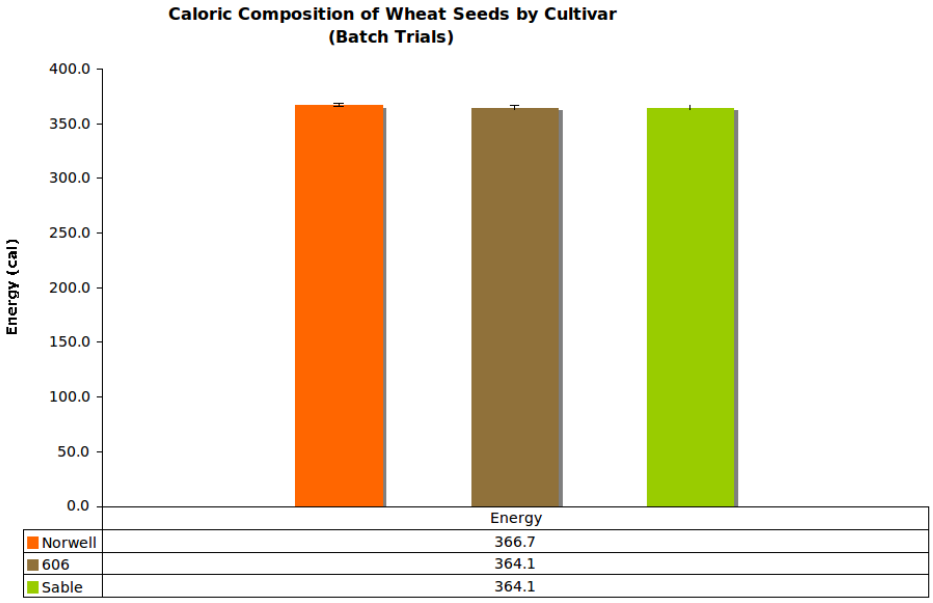


Illustration 13: Batch culture caloric content of wheat kernels

Total caloric content of wheat kernels showed no differences between Sable, 606, and Norwell.

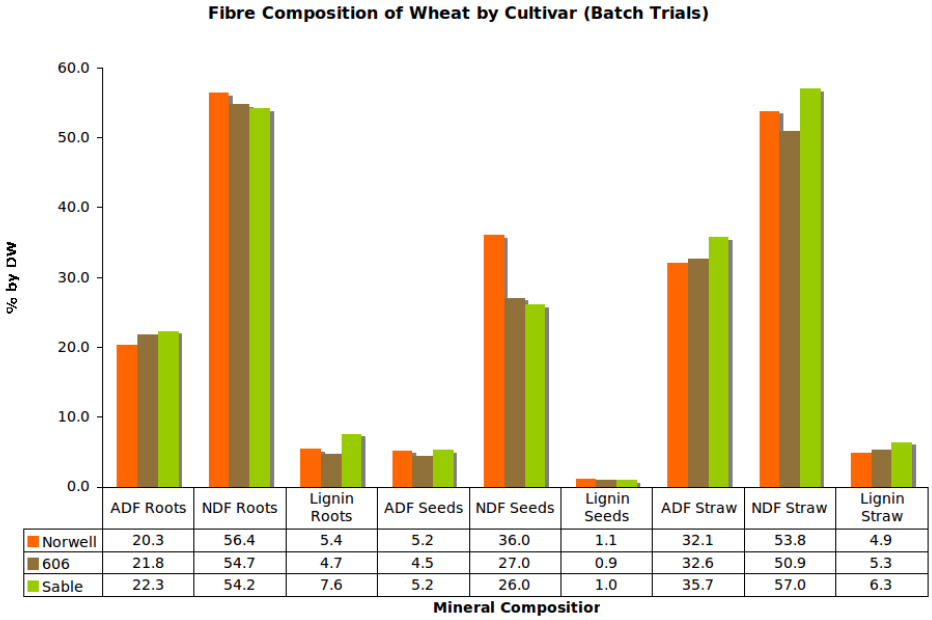


Illustration 14: Batch culture fibre composition

In general, there were no major differences in fibre content between the cultivars Norwell, 606, and Sable.

8 Conclusions

Based on harvest index and basic similarity in almost all compositional parameters, it is suggested that Norwell be used in HPC trials at UAB.

Appendix 1: Results of nutrient solution analysis for mixed batch culture

GW 1006 - Wheat trials with 3 spring cultivars (606, Norwell, Sable) - Dionex nutrient solution analysis n CH-1

Date		F	Cl	NO2	NO3	PO4	SO4	Na	NH4	K	Mg	Ca
Oct18/06	Start1	0	3.08	0	794.97	129.06	178.89	0	76.63	153.71	16.02	128.61
	Start2	0	2.97	0	811.28	131.36	182.12	0	77.23	157.02	16.61	132.15
	Start3	0	3.11	0	800.56	129.49	180.59	0	76.75	156.24	16.73	130.98
Oct23/06	End1	0	2.64	0	663.02	98.56	162.86	0	52.67	118.13	14.02	113.7
	End2	0	2.61	0	666.45	99.36	153.07	0	53.63	118.75	14.29	115.75
	End3	0	2.62	0	667.42	99.04	153.4	0	54.11	119.12	14.62	114.67
Oct23/06	Start1	0	3.09	0	839.95	137.17	203.6	0	83.65	167.37	17.93	137.61
	Start2	0	2.97	0	832.61	135	202	0	84.75	165.41	17.53	136.83
	Start3	0	3.2	0	827.41	135.36	200.85	0	81.67	165.95	17.78	136.49
Oct28/06	End1	0	2.05	0	683.77	99.08	181.2	0	36.65	105.14	17.47	135.36
	End2	0	1.9	0	674.92	97.03	179.85	0	37.01	104.58	17.18	135.22
	End3	0	1.83	0	685.38	98.73	169.8	0	36.77	106.74	17.46	137.13
Oct28/06	Start1	0	2.96	0	826.12	135.2	200.78	0	82.2	172.78	18.53	137.32
	Start2	0	2.89	0	820.81	134.12	199.77	0	81.22	172.44	18.1	137
	Start3	0	2.96	0	829.34	135.69	201.14	0	84.36	173.86	18.6	138.1
Nov2/06	End1	0	1.63	0	588.03	79.28	176.37	0	15.6	69.28	18.76	138.53
	End2	0	1.57	0	579.92	79.46	163.2	0	15.47	69.41	18.42	138.24
	End3	0	1.47	0	584.42	81.06	175.68	0	15.54	69.32	18.89	139.02
Nov2/06	Start1	0	4.06	0	794.57	128.71	182.83	5.96	98.98	185.81	17.74	152
	Start2	0	4.04	0	800.42	128.96	207.58	6.13	99.02	187.39	18.66	154.68
	Start3	0	4	0	800.43	129.88	184.26	5.82	100.52	189.01	18.96	157.29
Nov7/06	End1	0	1.73	0	365.85	25.61	161.08	5.15	0	0	18.11	160.19
	End2	0	1.63	0	353.7	24.82	156.61	5.02	0	0	17.19	155.29
	End3	0	1.61	0	353.47	24.62	157.21	6.14	0	0	17.8	155.71
Nov7/06	Start1	0	4	0	802.84	129.74	185.06	7.78	99.15	189.67	19.87	160.96
	Start2	0	3.93	0	805.52	130.73	185.92	8.05	98.59	192.01	20.5	162.35
	Start3	0	4.08	0	813.53	131.88	187.24	7.95	100.92	193.53	20.31	163.25
Nov12/06	End1	0	1.43	0	253.21	15.68	149.52	0.71	0	0	10.73	144.87
	End2	0	1.48	0	252.84	15.33	148.5	0.72	0	0	11.1	142.92
	End3	0	1.42	0	253.13	15.36	149.49	0.59	0	0	11.16	143.96
Nov12/06	Start1	0	4.08	0	812.41	131.74	212.53	7.17	105.96	195.76	21.01	165.15
	Start2	0	4.03	0	806.28	131.27	211.44	7.22	106.97	195.17	21.19	163.64
	Start3	0	3.94	0	816.07	132.1	187.93	7.11	110.05	196.81	21.5	165.59
Nov17/06	End1	0	1.19	0	254.22	11.48	139.79	3.41	4.65	0	11.52	129.14
	End2	0	1.17	0	252.41	11.39	139.61	3.04	4.56	0	11.43	132.15
	End3	0	1.26	0	252.84	11.24	138.72	2.71	4.47	0	10.72	130.72
Nov17/06	Start1	0	2.85	0	819.18	134.12	185.49	11.21	99.78	182.88	22.18	151.63
	Start2	0	2.9	0	827.64	134.22	197.54	11.53	86.9	184.21	21.88	153.58
	Start3	0	2.9	0	818.52	133.29	195.4	11.46	101.87	183.11	21.64	152.43
Nov22/06	End1	0	1.31	0	274.2	0	129.27	3.81	4.44	0	12.21	128.81
	End2	0	1.41	0	278.86	0	131.61	3.32	4.76	0	12.39	131.99
	End3	0	1.25	0	279.68	0	131.63	3.52	4.69	0	12.53	132.05

Nov22/06	Start1	0	2.98	0	829.16	133.28	197.16	10.98	97.8	185.27	22.42	154.98
	Start2	0	2.94	0	821.32	133.11	184.15	11.04	99.3	183.74	22.1	154.46
	Start3	0	3.03	0	839.51	135.04	199.85	11.23	99.4	188.09	22.36	159.23
Nov27/06	End1	0	1.41	0	303.97	0	122.3	3.83	4.79	0	13.52	134.97
	End2	0	1.34	0	301.39	0	122.01	3.59	4.41	0	12.78	135.55
	End3	0	1.39	0	303.32	0	123.03	3.64	4.9	0	13.82	137.24
Nov27/06	Start1	0	3.05	0	848.5	138.25	202.31	10.13	99.94	191.5	24	162.07
	Start2	0	3.17	0	846.88	136.83	202.24	9.56	100.65	189.94	22.87	160.05
	Start3	0	3.05	0	841.91	136.52	190.33	8.78	101.55	189.33	23.04	159.41
Dec2/06	End1	0	1.35	0	319.85	0	109.97	1.65	4.86	0	13.41	131.91
	End2	0	1.41	0	319.18	0	109.02	1.98	4.68	0	14.3	131.15
	End3	0	1.36	0	319.64	0	109.62	2.11	4.77	0	14.07	129.6
Dec2/06	Start1	0	3.16	0	828.68	134.54	198.07	9.66	100.69	188.06	22.66	159.69
	Start2	0	3.33	0	831.84	135.19	199.27	9.84	102.02	188.83	23.29	158.82
	Start3	0	3.33	0	831.31	134.94	199.6	9.84	96.95	190.13	23.61	159.48
Dec7/06	End1	0	1.76	0	331.18	0	92.77	1.62	0	0	12.8	119.58
	End2	0	1.61	0	337.61	0	94.49	1.26	6.48	0	12.38	122.81
	End3	0	1.57	0	339.25	0	95.28	1.16	6.67	0	13.5	126.41
Dec7/06	Start1	0	3.77	0	822.7	133.37	210.92	6.11	98.68	187.82	21.33	158.53
	Start2	0	3.83	0	822.85	133.23	184.4	6	96.49	189.15	20.97	161.72
	Start3	0	3.77	0	819.72	133.54	184.43	5.83	95.92	188.21	21.5	156.98
Dec12/06	End1	0	1.7	0	434.41	0	111.57	10.05	5.93	0	16.92	139.13
	End2	0	1.81	0	430.38	0	111.67	9.82	5.34	0	16.98	139.35
	End3	0	1.73	0	431.11	0	111.6	9.34	5.41	0	17.22	138.6
Dec12/06	Start1	0	3.79	0	835.88	135.83	186.72	5.75	96.27	189.59	21.65	161.74
	Start2	0	3.84	0	824.2	132.89	183.67	5.84	95.74	188	21.12	159.62
	Start3	0	3.8	0	809.88	130.07	180.75	7.15	93.08	185.48	21.08	156.39
Dec17/06	End1	0	1.9	0	558.79	0	140.36	12.89	6	49.55	20.56	150.03
	End2	0	1.86	0	560.33	0	139.85	13.61	5.16	47.98	20.35	150.55
	End3	0	1.85	0	563.23	0	141.48	15.09	6.3	48.74	20.19	153.77
Dec17/06	Start1	0	3.98	0	851.54	138.8	189.71	5.27	100.19	194.64	22.89	164.63
	Start2	0	3.96	0	843.53	137.57	215.12	5.48	98.57	195.29	21.88	164.8
	Start3	0	3.82	0	843.33	136.82	188.65	5.48	98.12	193.69	22.58	167.55
Dec22/06	End1	0	0.96	0	230.26	0	132.02	9.87	4.61	13.49	14.1	130.15
	End2	0	1	0	229.66	0	131.07	13.94	5.79	12.97	13.81	129.71
	End3	0	0.98	0	228.87	0	131.72	13.74	5.99	13.41	13.69	128.59
Dec22/06	Start1	0	3.86	0	842.88	135.93	186.98	14.22	115.21	202.48	22.73	169.43
	Start2	0	3.95	0	844.69	136.88	214.46	13.76	107.33	201.08	22.37	168.4
	Start3	0	3.98	0	852.77	138.01	189.28	13.2	109	197	21.4	165.83
Dec27/06	End1	0	1.73	0	418.04	0	138.91	14.04	6.65	38.73	14.8	145.69
	End2	0	1.68	0	418.6	0	138.84	10.99	5.05	38.68	15.53	143.05
	End3	0	1.68	0	421.8	0	139.47	10.98	5.37	37.36	15.53	142.46
Dec27/06	Start1	0	3.88	0	836.37	136.36	189.46	8.64	99.72	190.76	21.91	156.91
	Start2	0	3.69	0	828.89	136.7	188.59	9.46	97.44	190.66	21.31	156.69
	Start3	0	3.79	0	842.22	137.49	190.26	9.06	99.84	191.35	22.09	158.43
Jan1/07	End1	0	1.04	0	244.94	0	125.68	8.7	5.48	5.42	11.9	126.9
	End2	0	1.04	0	246.63	0	126.84	8.89	5.19	5.52	12.59	127.14
	End3	0	0.96	0	249.35	0	128.37	9.25	5.82	5.38	11.83	128.08

Jan1/07	Start1	0	3.79	0	831.58	135.25	187.72	8.78	97.46	186.75	21.74	158.9
	Start2	0	3.85	0	837.23	136.37	214.77	8.92	97.43	187.96	20.92	157.64
	Start3	0	3.82	0	839	136.33	188.76	8.86	94.91	184.39	21.47	157.33
Jan6/07	End1	0	1.01	0	260.92	0	126.38	9.54	5.64	6.87	11.93	128.93
	End2	0	1.04	0	260.78	0	126.87	8.99	6.1	6.63	11.94	129.23
	End3	0	1.18	0	263.05	0	127.33	9.8	5.32	6.88	11.64	129.2
Jan6/07	Start1	0	3.97	0	849.85	140.05	192.42	6.18	98.44	191.55	22.65	161.71
	Start2	0	4	0	854.2	139.48	193.07	6.08	97.77	191.75	21.73	160.37
	Start3	0	3.9	0	854.06	140.07	219.07	6	100.68	189.77	22.33	156.7
Jan11/07	End1	0	1.88	0	440.37	0	137.35	7.79	4.61	52.57	15.1	135.23
	End2	0	1.83	0	440.76	0	137.72	8.31	5.03	51.21	14.89	139.48
	End3	0	1.79	0	439.53	0	136.78	8.28	4.51	51.89	15.1	139.27
Jan11/06	Start1	0	3.99	0	845.73	140.06	192.99	6.76	97.9	188.15	22.18	159.38
	Start2	0	3.86	0	849.27	139.9	193.68	6.41	96.42	190.06	21.97	158
	Start3	0	5.5	0	849.83	140.9	193.63	7.74	98.86	190.35	22.1	158.04
Jan16/07	End1	0	2.04	0	541.33	0	148.24	8.65	4.66	91	17.24	145.77
	End2	0	2.06	0	535.37	0	147.04	8.23	4.32	90.2	17.27	144.98
	End3	0	2.14	0	538.71	0	147.48	8.29	4.24	90.74	17.72	146.03
Jan16/07	Start1	0	3.83	0	819.51	136.17	213.69	5.88	92.57	183.69	21.73	151.87
	Start2	0	3.92	0	812.23	135.59	187.43	5.9	92.2	181.26	20.91	149.58
	Start3	0	3.88	0	815.62	135.58	186.65	5.97	90.89	180.29	20.9	150.12
Jan21/07	End1	0	2.11	0	591.83	36.67	155.84	7.35	8.02	125.35	18.83	146.62
	End2	0	2.1	0	588.82	36.23	154.25	5.96	7.9	124.22	18.69	145
	End3	0	2.03	0	589.87	36.32	154.85	7.3	7.96	124.14	18.14	146.93

GW1106 - Wheat -Trials with 3 spring wheat cultivars (Norwell, Sable, 606) in CH-2

Sample name		F	Cl	NO2	NO3	PO4	SO4	Na	NH4	K	Mg	Ca
Nov7/06	Start1	0	4.48	0	803.09	131.4	181.99	9.67	98.51	180.94	22.4	154.15
	Start2	0	4.12	0	809.77	131.63	207.85	9.28	100.08	183.29	22.29	155.16
	Start3	0	3.92	0	804.96	131.48	207.13	9.12	98.91	182.31	21.96	154.61
Nov12/06	End1	0	5.39	0	723.63	112.7	172.13	10.5	79.44	153.83	20.82	147.73
	End2	0	3.45	0	731.18	113.86	193	8.83	79.11	155.12	20.88	149.02
	End3	0	3.39	0	731.75	114.38	170.37	8.96	80.15	155	21.09	149.18
Nov12/06	Start1	0	4.05	0	818.49	133.11	208.67	9.36	98.35	184.42	22.2	157.23
	Start2	0	3.86	0	815.89	133.43	208.57	9.47	100.21	183.91	22.48	157.27
	Start3	0	3.98	0	820.84	133.47	184.21	9.28	97.04	185.93	22.29	158.98
Nov17/06	End1	0	2.6	0	656.57	91.26	189.26	9.52	53.57	117.55	21.38	152.64
	End2	0	2.68	0	655.46	90.06	168.83	13.07	53.44	116.97	21.22	151.51
	End3	0	2.53	0	662.89	92.37	167.39	9.41	53.14	117.02	21.3	152.48
Nov17/06	Start1	0	4	0	817.31	135.43	186.14	8.57	100.04	184.89	22.87	156.13
	Start2	0	3.96	0	815.58	134.38	210.44	8.38	97.39	185.07	22.67	155.43
	Start3	0	4.24	0	821.56	135.11	186.32	8.55	97.57	184.43	22.25	155.26
Nov22/06	End1	0	1.6	0	495.43	52.76	154.13	8.51	5.26	47.49	21.74	150.49

	End2	0	1.57	0	496.05	53.45	154.94	8.83	5.17	46.73	21.83	152.17
	End3	0	1.98	0	503.54	50.17	165.46	23.65	8.05	48.66	23.42	159.07
Nov22/06	Start1	0	4.03	0	821.66	134.69	185.41	7.9	98.52	186.21	22.14	156.47
	Start2	0	4	0	814.7	133.3	184.3	7.7	96.9	182.8	22.4	157
	Start3	0	3.88	0	819.97	135.17	185.56	7.56	98.27	184.09	22.33	156.09
Nov27/06	End1	0	1.66	0	370.02	24.94	151.56	7.27	0	0	20.85	153.2
	End2	0	1.79	0	367.95	25.12	151.58	7.69	0	0	20.38	152.7
	End3	0	1.67	0	368.18	25.45	151.48	7.43	0	0	20.6	153.37
Nov27/06	Start1	0	4.07	0	822.97	134.7	186.36	7.01	98.63	183.91	22.28	156.65
	Start2	0	4.32	0	814.78	133.24	209.75	7.2	97.73	182.6	22.39	155.61
	Start3	0	4.03	0	816.91	134.39	210.5	6.9	98.9	183.69	22.81	156.64
Dec2/06	End1	0	1.31	0	228.25	11.3	144.23	1.35	0	0	11.77	139.36
	End2	0	1.32	0	226.33	11.08	145.41	1.41	0	0	11.79	140.19
	End3	0	1.36	0	226.94	11.07	145.76	1.33	0	0	11.83	140.29
Dec2/06	Start1	0	4.08	0	819.88	135.88	212.63	8.21	100.28	186.53	22.99	157.53
	Start2	0	4.06	0	815.59	134.63	186.31	8.15	100.08	186.26	22.84	157.25
	Start3	0	4.23	0	819.93	135.51	187.61	8.11	100.08	185.49	22.82	156.86
Dec7/06	End1	0	1.2	0	186.58	0	137.94	1.02	0	0	7.81	129.58
	End2	0	1.29	0	187.55	0	138.69	1.54	0	0	7.64	130.03
	End3	0	1.81	0	187.92	0	139.43	1.66	0	0	7.76	130.93
Dec7/06	Start1	0	4.56	0	786.76	128.48	177.67	7.18	102.81	186.7	22.78	157.8
	Start2	0	4.02	0	797.2	129.95	180.41	7.03	103.66	189.01	22.95	159.11
	Start3	0	4.82	0	804.1	131.21	181.95	7.82	105.14	188.52	22.67	156.32
Dec12/06	End1	0	1.58	0	274.2	14.63	142.49	0.92	0	0	14.93	132.48
	End2	0	1.64	0	273.98	14.46	142.42	1.53	0	0	15.23	130.83
	End3	0	1.94	0	280.17	15.2	154.59	1.6	0	0	15.54	134.19
Dec12/06	Start1	0	4.52	0	826.09	134.4	186.03	8.68	98.52	182.89	22.57	154.07
	Start2	0	4.03	0	817.12	133.62	210.03	8.4	97.9	180.94	22.27	152.89
	Start3	0	3.97	0	821.15	134.44	185.55	8.09	97.39	180.96	22.44	153.83
Dec17/06	End1	0	1.76	0	343.92	8.66	139.54	2.33	0	0	17.83	142.31
	End2	0	1.89	0	341.21	8.94	138.39	2.02	0	0	17.94	141.35
	End3	0	2.02	0	344	8.87	140.15	2.09	0	0	17.9	141.76
Dec17/06	Start1	0	4.16	0	824.15	135.47	187.22	7.97	99.37	183.33	22.48	153.33
	Start2	0	4.12	0	839.14	136.95	189.89	8.06	99.68	185.07	22.78	156.38
	Start3	0	4.19	0	829.5	136.09	213.35	7.97	99.03	182.91	22.42	154.97
Dec22/06	End1	0	1.03	0	182.3	0	66.22	1.15	0	0	3.67	106.13
	End2	0	1.28	0	183.72	0	67.42	1.49	0	0	3.81	106.73
	End3	0	1.05	0	183.75	0	66.97	1.08	0	0	3.62	107.43
Dec22/06	Start1	0	4.26	0	814.01	131.56	183.05	14.04	98.9	179.39	22.18	153.62
	Start2	0	4.15	0	806.76	130.34	181.73	13.21	97.01	177.31	21.9	153.27
	Start3	0	4.15	0	808.1	131.58	182.9	13.9	97.34	177.72	22.08	153.43
Dec27/06	End1	0	1.72	0	311.44	0	107.74	1.34	0	0	12.97	127.24
	End2	0	1.68	0	313.61	0	108.13	1.49	0	0	13.02	128.28
	End3	0	1.69	0	316.24	0	109.5	1.4	0	0	13.19	129.41
Dec27/06	Start1	0	4.33	0	829.09	136.25	214.19	10	100.13	183.79	22.97	154.71
	Start2	0	4.06	0	828.2	135.71	187.83	11.7	100.87	183.05	22.75	154.71
	Start3	0	4.08	0	818.65	134.54	186.72	11.28	98.58	182.72	22.73	154.7
Jan1/07	End1	0	0	0	88	0	44.92	3.29	0	0	2.79	85.65

	End2	0	0	0	86.07	0	46.52	4.1	0	0	2.86	85.58
	End3	0	0	0	86.18	0	45.27	3.24	0	0	2.71	85.69
Jan1/07	Start1	0	4.05	0	783.07	128.17	178.52	11.44	95.49	173.84	21.74	148.53
	Start2	0	4.22	0	777.78	127.65	177.58	11.56	93.86	173.63	21.66	148.39
	Start3	0	4.09	0	771.22	126.83	200.65	11.08	93.92	173.08	21.65	147.84
Jan6/07	End1	0	0	0	103.26	0	67.06	4.07	0	0	4.03	99.02
	End2	0	0	0	103.22	0	66.79	4.23	0	0	4.04	100.66
	End3	0	0	0	102.97	0	67.3	4.67	0	0	3.86	98.67
Jan6/07	Start1	0	3.86	0	836.12	136.39	211.03	9.44	103.68	184.23	23.29	159.39
	Start2	0	5.81	0	828.46	135.64	213.7	11.75	102.1	183.37	23.68	158.87
	Start3	0	3.99	0	825.52	134.24	183.92	9.16	101.63	181.83	22.89	156.75
Jan11/07	End1	0	1.65	0	404.02	0	120.17	14.39	0	8.33	16.3	143.86
	End2	0	1.69	0	400.38	0	120.06	14.53	0	8.38	16.33	143.45
	End3	0	1.57	0	405.45	0	120.96	14.44	0	8.35	16.58	144.76
Jan11/07	Start1	0	4.01	0	808.81	134.35	209.23	11.01	100.93	181.74	22.89	154.77
	Start2	0	3.92	0	799.69	132.51	206.24	10.92	101.51	179.65	22.76	153.19
	Start3	0	3.94	0	793.95	132.31	181.39	10.75	99.95	179.37	22.66	153.83
Jan16/07	End1	0	1.98	0	507.47	0	144.73	17.74	0	45.86	21.5	152.75
	End2	0	1.88	0	507.2	0	144.44	18.06	0	45.43	21.54	152.99
	End3	0	1.78	0	511.26	0	145.23	18.17	0	45.92	21.94	153.81
Jan16/07	Start1	0	4.56	0	806.2	133.04	208.9	12.02	101.45	182.25	23.13	155.18
	Start2	0	4.7	0	799.14	131.83	182.91	12.42	101.29	180.39	23.06	154.46
	Start3	0	4.25	0	798.32	132.38	206.44	11.65	99.48	179.5	22.91	153.28
Jan21/07	End1	0	1.9	0	340.99	0	148.71	18.41	0	33.08	17.92	140.89
	End2	0	1.95	0	321.33	0	142.11	17.71	0	31.22	17.26	134.47
	End3	0	1.95	0	325.93	0	143.73	17.52	0	31.79	17.55	137
Jan21/07	Start1	0	4.23	0	802.81	130.99	205.52	12.48	101	179.47	22.79	154.88
	Srart2	0	4.24	0	795.18	131.01	181.16	12.31	100.75	178.31	22.47	154.52
	Start3	0	4.37	0	798	130.32	181.64	12.51	101.13	179.77	23.05	155.47
Jan26/07	End1	0	2.04	0	430.52	0	143.21	16.22	0	66.6	16.94	144.1
	End2	0	2.46	0	430.39	0	143.57	16.3	0	66.9	17.38	144.95
	End3	0	2.06	0	437.01	0	145.34	16.24	0	67.72	17.53	146.51
Jan26/07	Start1	0	4.52	0	805.47	132.82	185.43	13.43	101.45	182.45	23.1	156.02
	Start2	0	4.61	0	801.28	132.74	209.05	13.52	102.97	183.32	23.26	156.92
	Srart3	0	4.37	0	801.6	132.71	208.5	13.52	101.37	182.25	23.51	156.44
Jan31/07	End1	0	1.71	0	350.56	0	137.21	15.82	0	62.11	15.31	137.94
	End2	0	1.89	0	352.33	0	137.98	15.97	0	62.09	15.61	138.49
	End3	0	1.9	0	354.23	0	138.06	15.78	0	62.88	15.53	138.27
Jan31/07	Start1	0	3.01	0	832.15	136	0	9	106.63	193.02	16.16	152.23
	Start2	0	3.25	0	848.35	139.78	187.06	8.89	105.97	193.65	15.84	152.91
	Start3	0	3.33	0	863.28	142.18	189.44	9.06	108.72	195.03	17.03	156.58
Feb5/07	End1	0	0	0	323.96	0	131.72	10.19	0	48.55	7.86	129.96
	End2	0	0	0	325.73	0	132.32	10.04	0	48.36	8.2	130
	End3	0	0	0	322.43	0	131.13	10.03	0	47.86	9.09	131.22
Feb5/07	Start1	0	3.78	0	871.85	142.3	192.55	9.08	106.96	194.26	17.49	157.31
	Start2	0	3.65	0	864.96	140.3	191.59	9.23	108.5	194.71	18.11	156.76
	Start3	0	3.61	0	857.92	138.49	190.73	9.04	107.8	193.84	18.09	158.42
Feb10/07	End1	0	1.46	0	412.98	18.33	131.66	9.43	0	73.89	11.08	132.01

End2	0	1.53	0	396.69	17.63	129	9.26	0	72.67	11.37	130.49
End3	0	1.55	0	391.37	17.26	126.47	9.13	0	71.84	11.78	128.85

Appendix 2: Results of nutrient solution analysis for batch culture

GW 0207a - Wheat batch production in CH-1 with Norwell - Dionex nutrient solution analysis

Sample name		F	Cl	NO2	NO3	PO4	SO4	Na	NH4	K	Mg	Ca
Feb13/07	Start1	0	3.39	0	808.04	131.06	184.45	17.27	107.58	180.68	27.05	150.09
	Start2	0	3.31	0	808.53	131.52	182.1	17.07	106.81	179.15	26.87	148.73
	Start3	0	3.23	0	808.84	133.12	184.48	17.14	106.29	178.86	26.96	149.62
Feb19/07	End1	0	2.30	0	665.98	96.00	154.64	15.82	69.88	132.15	24.11	132.41
	End2	0	2.42	0	669.45	97.85	155.39	15.84	70.70	131.74	23.92	132.53
	End3	0	2.39	0	667.10	98.31	156.85	15.74	70.71	131.77	24.20	132.70
Feb19/07	Start1	0	3.60	0	813.54	134.10	186.52	17.23	104.55	178.00	26.77	147.46
	Start2	0	3.36	0	817.00	134.77	185.52	17.15	103.43	177.72	26.53	147.88
	Start3	0	3.37	0	821.78	135.47	187.27	17.21	105.10	177.79	26.58	147.69
Feb23/07	End1	0	1.96	0	708.33	96.99	174.01	17.49	58.40	126.26	26.47	147.21
	End2	0	2.07	0	713.82	98.07	175.69	17.43	57.94	126.47	26.57	147.33
	End3	0	1.92	0	713.32	97.84	175.63	17.36	85.16	126.69	26.56	148.23
Feb23/07	Start1	0	3.43	0	840.63	138.80	190.93	16.72	104.79	180.73	26.69	150.91
	Start2	0	3.58	0	839.25	138.42	191.45	16.88	106.04	180.79	26.51	151.59
	Start3	0	3.33	0	836.63	138.5	190.45	16.57	104.26	180.19	26.78	150.57
Feb28/07	End1	0	1.11	0	596.35	66.61	169.93	17.46	21.60	72.08	27.09	152.39
	End2	0	1.04	0	597.77	67.39	171.14	17.42	21.44	72.45	27.38	152.71
	End3	0	1.01	0	601.28	66.87	171.19	17.46	21.34	72.21	27.33	152.26
Feb28/07	Start1	0	3.45	0	839.56	141.10	194.43	17.28	106.79	183.94	27.25	150.19
	Start2	0	3.54	0	841.59	141.11	194.47	17.41	107.61	184.41	27.12	150.92
	Start3	0	3.42	0	836.11	140.42	193.12	17.17	106.84	183.79	27.24	149.79
Mar5/07	End1	0	1.21	0	455.25	26.42	167.17	17.83	3.16	0	28.34	157.31
	End2	0	1.11	0	453.21	26.33	166.11	17.78	3.23	0	28.30	157.34
	End3	0	1.26	0	452.13	26.32	166.12	18.02	3.62	0	28.31	157.34
Mar5/07	Start1	0	3.47	0	839.27	138.90	191.63	15.67	107.04	183.22	27.05	152.70
	Start2	0	3.47	0	835.66	137.92	189.87	15.42	104.62	182.32	27.07	151.64
	Start3	0	3.50	0	833.62	137.62	190.06	15.65	107.98	182.89	26.87	152.26
Mar9/07	End1	0	1.23	0	443.30	35.85	165.68	16.06	4.41	0	28.08	159.73
	End2	0	1.11	0	440.56	35.43	164.59	15.97	3.39	0	28.00	158.63
	End3	0	1.11	0	444.57	35.65	165.63	16.41	3.42	0	28.18	159.26
Mar9/07	Start1	0	3.37	0	835.07	135.87	188.13	14.75	106.60	181.67	26.85	153.64
	Start2	0	3.42	0	831.83	134.48	188.45	14.76	105.40	182.22	27.00	153.67
	Start3	0	3.43	0	824.63	134.21	187.56	15.03	106.87	181.58	26.76	152.27
Mar15/07	End1	0	1.23	0	370.76	13.93	153.43	13.40	4.75	0	24.55	146.42
	End2	0	1.06	0	365.82	13.23	152.43	11.46	3.26	0	24.51	145.55
	End3	0	1.07	0	362.96	13.17	150.83	11.43	3.52	0	24.31	144.82
Mar15/07	Start1	0	3.39	0	814.09	132.19	183.28	14.23	105.96	179.17	26.43	150.14
	Start2	0	3.31	0	811.51	131.25	183.88	14.11	104.91	179.53	26.45	150.10
	Start3	0	3.37	0	806.19	131.16	183.56	14.10	104.60	178.80	26.48	150.64
Mar20/07	End1	0	1.34	0	392.43	9.83	135.88	11.18	4.73	0	23.92	142.65
	End2	0	1.17	0	387.45	9.50	134.27	11.34	5.67	0	23.82	142.39

	End3	0	1.17	0	389.09	9.49	135.00	11.42	5.48	0	24.05	142.92
Mar20/07	Start1	0	3.36	0	814.07	132.63	186.22	14.32	106.97	182.18	26.96	152.05
	Start2	0	3.38	0	809.44	131.49	185.01	14.22	105.20	181.50	26.68	150.90
	Start3	0	3.34	0	806.11	131.45	184.75	14.33	106.04	181.53	26.70	151.64
Mar26/07	End1	0	1.14	0	341.19	0	113.37	8.26	3.70	0	21.15	129.41
	End2	0	1.14	0	341.04	0	113.90	7.90	3.37	0	21.20	129.79
	End3	0	1.18	0	341.95	0	113.33	8.04	3.74	0	21.08	130.21
Mar26/07	Start1	0	3.38	0	814.46	132.55	212.45	15.90	106.72	183.29	27.05	155.30
	Start2	0	4.33	0	806.07	128.60	183.38	16.73	103.12	181.61	26.89	152.44
	Start3	0	3.29	0	806.57	129.63	210.58	15.99	106.39	181.60	26.89	152.60
Mar30/07	End1	0	1.18	0	413.23	0	127.70	17.19	7.63	7.28	23.30	136.77
	End2	0	1.24	0	414.31	0	128.96	17.15	6.21	0	23.56	137.35
	End3	0	1.17	0	414.41	0	128.45	17.18	5.98	0	23.38	137.47
Mar30/07	Start1	0	3.35	0	781.65	125.46	174.64	16.12	102.71	173.9	26.11	147.17
	Start2	0	3.26	0	775.48	124.47	173.8	16.31	102.71	172.8	25.66	146.87
	Start3	0	3.22	0	777.91	124.95	174.63	16.36	104.09	174.04	25.94	146.70
April4/07	End1	0	1.27	0	409.28	0	120.08	18.85	3.80	9.63	23.52	133.51
	End2	0	1.25	0	409.75	0	120.23	18.87	3.38	9.45	23.10	133.83
	End3	0	1.32	0	415.94	0	121.05	18.61	3.35	9.97	23.71	135.67
April4/07	Start1	0	3.44	0	811.17	132.69	184.66	14.70	106.76	182.31	27.10	152.73
	Start2	0	3.42	0	812.36	133.24	185.03	14.98	106.58	181.82	26.69	151.02
	Start3	0	3.49	0	818.48	134.44	186.24	15.20	108.40	181.83	27.18	152.20
April9/07	End1	0	1.42	0	452.34	0	143.14	16.89	3.83	61.85	23.28	135.81
	End2	0	1.44	0	458.17	0	145.05	17.21	4.08	61.91	23.28	136.73
	End3	0	1.41	0	460.40	0	145.31	17.14	3.85	61.67	23.52	136.48
April9/07	Start1	0	3.46	0	813.90	132.79	212.88	13.17	106.33	179.98	26.78	150.74
	Start2	0	3.31	0	808.28	133.31	184.88	13.38	104.35	179.56	26.41	149.16
	Start3	0	3.42	0	804.63	134.01	184.40	12.93	105.05	179.81	26.05	148.62
April13/07	End1	0	1.60	0	569.79	17.63	155.36	15.10	3.54	112.81	24.76	147.51
	End2	0	1.74	0	563.19	16.88	153.64	14.69	3.31	110.55	25.16	145.30
	End3	0	1.68	0	565.49	16.70	154.48	14.61	3.79	110.82	25.03	144.34
April13/07	Start1	0	3.50	0	815.44	133.72	186.53	17.13	104.24	179.23	26.99	150.96
	Start2	0	3.63	0	836.94	137.65	217.18	17.35	107.72	184.96	27.2	154.15
	Start3	0	5.04	0	818.14	134.78	186.85	16.78	104.40	178.48	26.86	149.98
April19/07	End1	0	1.66	0	482.31	21.64	149.58	16.86	3.53	95.73	23.13	133.24
	End2	0	1.46	0	473.01	21.39	146.22	16.64	4.14	94.11	22.57	130.07
	End3	0	1.50	0	471.30	21.13	146.59	16.95	4.71	93.58	22.09	130.55
April19/07	Start1	0	3.57	0	833.86	136.74	217.73	17.27	107.35	181.24	26.86	154.64
	Start2	0	3.53	0	832.54	136.94	190.46	17.04	105.93	180.26	27.12	152.97
	Start3	0	3.53	0	837.70	136.84	190.76	17.09	106.59	181.24	27.20	153.73
April24/07	End1	0	1.39	0	441.37	22.44	141.38	16.78	3.46	75.55	21.63	131.65
	End2	0	1.38	0	437.37	21.74	140.54	16.81	3.48	74.94	21.84	131.64
	End3	0	1.39	0	443.71	22.47	143.33	17.10	3.88	75.84	22.01	132.91
April24/07	Start1	0	3.70	0	837.16	138.36	192.54	16.91	104.40	182.42	26.64	155.21
	Srart2	0	3.56	0	835.67	138.30	219.34	16.73	106.54	181.32	26.98	153.75
	Start3	0	3.53	0	830.54	137.07	218.40	16.73	105.56	180.33	26.83	152.64
April30/07	End1	0	3.46	0	824.09	135.66	216.21	18.55	104.83	177.74	26.49	151.92
	End2	0	3.53	0	831.11	136.16	189.83	18.36	104.68	178.50	26.56	152.48

	End3	0	3.51	0	835.64	137.82	191.66	18.52	105.41	180.05	26.94	153.23
April30/07	Srtart1	0	1.51	1.52	502.27	41.43	143.22	16.28	44.39	138.52	20.84	114.30
	Start2	0	1.50	1.58	504.05	40.94	143.63	16.69	44.10	138.33	20.66	113.96
	Start3	0	1.50	0	507.89	40.73	144.20	16.34	43.38	138.93	20.78	114.61
May4/07	End1	0	1.22	13.10	600.45	87.10	152.14	15.92	89.74	142.21	21.68	112.71
	End2	0	1.24	13.20	604.17	87.45	153.25	15.96	90.55	142.69	21.39	113.25
	End3	0	1.24	13.50	604.76	88.00	153.44	15.91	90.18	142.46	21.59	112.35

GW0507-606-Wheat Bach Production in CH-1 Dionex n utrient soution analysis with cultivar 606

Sample date		F	Cl	NO2	NO3	PO4	SO4	Na	NH4	K	Mg	Ca
May30/07	Start1	0	5.53	0	269.28	135.61	187.91	77.45	101.91	124.57	78.99	115.32
	Start2	0	5.67	0	273.75	137.3	193.21	76.56	101.46	125.71	78.13	116.09
	Start3	0	5.92	0	282.32	143.07	200.73	75.72	100.9	127.48	77.51	116.69
June4/07	End1	0	5.08	0	233.17	113.11	164.11	74.74	78.37	113.67	76.01	112.02
	End2	0	5.32	0	235.58	113.96	170.09	74	78.03	114.18	75.45	110.84
	End3	0	8.02	0	241.37	118.28	184.52	74.54	78.62	114.9	75.18	111.58
June4/07	Start1	0	6.21	0	292.93	151.96	216.64	73.62	99.11	128.18	75.57	117.72
	Start2	0	6.52	0	295.44	153.61	220.42	73.12	101.52	128.95	75.23	118.08
	Start3	0	6.45	0	294.58	135.42	222.29	72.78	99.58	128.83	74.86	118
June8/07	End1	0	5.23	0	255.88	120.55	205.28	72.36	72.43	113.67	74.2	116.17
	End2	0	5.15	0	255.21	121.93	273.74	71.42	72.47	113.88	73.39	116.45
	End3	0	5.22	0	255.1	120.78	208.15	71.02	72.4	113.77	73.24	116.59
June8/07	Start1	0	6.57	0	294.02	152.26	227.26	71.07	100.25	130.06	73.33	118.77
	Start2	0	6.6	0	289.79	149.26	223.34	71.47	99.73	130.8	73.08	118.63
	Start3	0	6.68	0	291.51	150.28	295.15	70.51	99.82	129.91	72.92	118.73
June14/07	End1	0	3.69	0	182.04	73.7	190.21	70.38	21.34	83.22	72.51	116.89
	End2	0	3.65	0	180.21	72.37	186.36	70.97	21.9	83.03	2.39	117.33
	End3	0	3.59	0	180.77	72.61	186.96	70.02	21.77	83.09	72.18	117
June14/07	Start1	0	6.53	0	288.98	147.59	224.14	70.04	100.88	131.11	72.34	120.05
	Start2	0	6.56	0	286.52	145.05	291.93	69.91	101.31	131.19	72.07	120.06
	Start3	0	6.3	0	276.08	138.37	206.79	69.36	100.35	130.11	71.6	119.16
June19/07	End1	0	3.38	0	132	53.76	164.73	69.15	0	0	71.07	117.58
	End2	0	3.18	0	131.64	53.67	163.74	69.01	0	0	70.98	117.93
	End3	0	3.14	0	130.21	52.9	160.18	68.95	0	0	70.91	118.07
June19/07	Start1	0	6.44	0	271.35	134.96	197.16	69.08	102.09	131.45	71.15	120.02
	Start2	0	6.16	0	268.93	132.76	266.57	68.96	101.71	131.12	70.97	119.64
	Start3	0	6.1	0	265.17	130.13	262.76	68.7	101.69	130.81	70.89	119.39
June25/07	End1	0	2.71	0	76.15	13.59	132.38	64.46	10.91	0	67.49	111.95
	End2	0	2.58	0	75.29	13.13	130.19	64.29	11.48	0	67.36	112.22
	End3	0	2.6	0	74.99	13.51	180.61	64.16	10.9	0	67.31	112.13
June25/07	Start1	0	5.85	0	253.24	120.88	241.9	67.74	102.2	130.73	70.23	119.21
	Start2	0	5.8	0	251.23	119.3	169.32	67.67	102.33	130.53	70.03	119.14
	Start3	0	5.7	0	249.37	118.05	235.55	67.41	102.33	130.46	69.92	119.27
June29/07	End1	0	2.87	0	108.61	56.18	196.63	67.05	31.48	0	68.6	115.13
	End2	0	2.79	0	107.95	55.56	136.78	66.83	31.35	0	68.6	115.5
	End3	0	2.79	0	106.37	54.32	133.23	66.61	31	0	68.34	115.31

June29/07	Start1	0	5.69	0	240.59	111.73	158	66.64	102.49	130.62	69.67	118.84
	Start2	0	5.59	0	239.53	110.53	156.34	66.56	102.93	130.44	69.53	119.11
	Start3	0	5.56	0	237.01	108.39	154.19	66.51	102.51	130.42	69.3	118.92
July4/07	End1	0	2.8	0	99.82	20.85	105.67	65.06	12.22	0	67.71	113.57
	End2	0	2.66	0	97.79	19.89	102.57	64.91	11.94	0	67.47	113.56
	End3	0	2.64	0	96.81	19.13	101.69	64.8	12.07	0	67.33	113.37
July4/07	Start1	0	5.4	0	230.29	102.42	214.44	65.57	104.32	131.5	69.18	120.24
	Start2	0	5.32	0	226.25	99.55	148.87	65.5	103.67	130.72	68.91	119.35
	Start3	0	5.41	0	226	98.6	209.81	65.56	103.75	131.08	68.89	119.41
July9/07	End1	0	2.57	0	94.55	0	97.03	62.85	11.01	0	66.62	112.56
	End2	0	2.48	0	93.81	0	145.89	62.76	11	0	66.5	111.84
	End3	0	2.51	0	92.83	0	143.35	62.72	10.99	0	66.37	111.48
July9/07	Start1	0	6.43	0	786.52	130.81	364.12	65.43	102.49	132.42	68.58	119.94
	Start2	0	6.64	0	789.16	130.93	371.02	65.27	102.34	132.63	68.57	120.31
	Start3	0	6.72	0	786.84	130.71	293.58	65.23	101.91	134.37	68.88	120.09
July14/07	End1	0	3.31	0	381.65	0	123.62	64.02	17.22	0	66.68	112.44
	End2	0	3.22	0	373.24	0	121.32	63.9	17.02	0	66.48	111.64
	End3	0	3.03	0	373.42	0	168.96	63.8	17.44	0	66.58	111.55
July14/07	Start1	0	6.6	0	783.31	130.78	366.27	65.3	101.94	131.88	68.5	119.72
	Start2	0	17.52	0	787.97	131.27	338.45	70.26	101.6	132.46	69.45	120.3
	Start3	0	6.46	0	787.95	131.47	229.51	65.55	101.95	132.12	68.58	121.06
July19/07	End1	0	3.41	0	361.01	0	89.84	64.21	0	0	65.95	108.15
	End2	0	2.9	0	361.22	0	87.88	63.48	0	0	65.78	107.34
	End3	0	2.85	0	360.19	0	88	63.45	0	0	65.69	107.06
July19/07	Start1	0	6.63	0	788.04	131.35	374.69	65.37	101.53	132.12	68.55	120.14
	Start2	0	6.6	0	794.59	132.14	234.51	65.24	102.35	132.85	68.67	120.64
	Start3	0	6.59	0	798.85	133.25	382.02	65.25	102.69	133.29	68.71	120.82
July24/07	End1	0	3.32	0	471.89	0	129.44	67.59	14.75	70.48	66.92	110.41
	End2	0	3.49	0	472.67	0	178.85	67.69	14.73	70.43	66.86	110.48
	End3	0	3.17	0	471.39	0	177.91	67.56	14.84	70.42	66.79	110
July24/07	Start1	0	6.53	0	788.36	130.61	227.69	66	101.19	131.47	68.56	120.72
	Start2	0	5.8	0	791.63	130.79	228.76	65.31	101.23	131.57	68.55	120.86
	Start3	0	6.8	0	789.99	130.32	372.83	65.32	101.48	131.49	68.5	120.22
July30/07	End1	0	3.65	0	506.93	0	232.75	68.54	0	98.38	67.05	114.39
	End2	0	3.58	0	505.41	0	156.76	68.52	0	98.38	67.03	114.2
	End3	0	3.52	0	506.55	0	230.49	68.47	0	98.31	67.06	114.22
July30/07	Start1	0	6.61	0	795.62	131.86	372.7	65.56	101.57	132.32	68.58	120.84
	Start2	0	6.69	0	793.63	131.41	377.28	65.54	101.84	132.27	68.6	120.68
	Start3	0	7.62	0	795.89	131.84	377.46	66.08	101.79	132.24	68.7	120.8
Aug3/07	End1	0	3.72	0	523.53	6.45	174.75	67.49	0	113.58	66.4	115.13
	End2	0	3.73	0	527.82	7.02	266.85	67.56	0	113.64	66.43	115.38
	End3	0	3.75	0	528	6.86	267.69	67.57	0	113.72	66.42	115.62
Aug3/07	Start1	0	6.62	0	781.52	131.25	199.17	66.84	101.32	131.93	68.63	119.58
	Start2	0	6.54	0	784.11	131.08	312.41	66.95	101.19	131.94	68.64	119.78
	Start3	0	6.56	0	782.54	130.35	188.34	66.99	101.13	132.02	68.67	120.2
Aug8/07	End1	0	3.62	0	488.4	20.3	196.36	67.07	0	103.93	66.54	115.85
	End2	0	4.12	0	490.17	20.35	196.25	67.37	10.08	104.35	66.69	116.52
	End3	0	3.73	0	488.96	20.52	189.92	67.18	10.85	104.36	66.64	116.38

Aug8/07	Start1	0	6.77	0	812.21	137.4	172.68	65.49	105.32	135.36	69.05	121.76
	Start2	0	6.82	0	811.6	137.49	224.27	65.77	105.48	135.55	69.05	121.76
	Start3	0	6.79	0	807.84	136.01	217.37	65.48	104.92	135.11	69	121.54
Aug13/07	End1	0	3.01	0	346.04	7.95	103.1	65.99	10.7	82.64	66.25	114.18
	End2	0	3.17	0	347.82	7.93	143.18	66.18	10.7	82.59	66.2	114.48
	End3	0	3.58	0	349.1	8.11	141.45	65.31	10.47	82.81	66.35	114.74
Aug13/07	Start1	0	6.75	0	816.01	135.13	130.05	65.64	104.5	133.93	68.91	122.79
	Start2	0	6.73	0	809.01	134.64	169.82	65.59	103.62	133.29	68.79	122.1
	Start3	0	6.84	0	820.11	137.09	168.54	65.66	104.5	134.53	68.91	123.06
Aug17/07	End1	0	3.13	0.95	294.69	15.19	106.39	65.8	11.07	78.6	65.78	110.76

GW 1007- Sable - Wheat production with cultivar Sable in CH-1

Sample date		F	CL	NO2	NO3	PO4	SO4	Na	NH4	K	Mg	Ca
Oct30/07	Start1	0	4.02	0	801.25	128.7	172.23	80.33	105.19	119.84	81.76	112.3
	Start2	0	3.68	0	802.66	128.85	172.71	80.17	104.71	119.45	81.75	112.05
	Start3	0	3.54	0	800.12	127.7	171.99	80.18	103.98	119.42	81.69	111.98
Nov5/07	End1	0	2.8	0	603.19	85.79	137.34	79.74	70.53	104.13	80.78	106.54
	End2	0	2.71	0	604.08	85.67	144.94	79.77	69.49	104.09	80.77	106.46
	End3	0	2.78	0	603.45	85.7	137.45	79.78	69.15	104.18	80.75	106.43
Nov5/07	Start1	0	3.66	0	798.38	126.98	171.62	80.26	103.68	119.27	81.67	111.98
	Start2	0	3.6	0	791.44	126.45	170.7	80.24	103.45	118.97	81.65	111.68
	Start3	0	3.59	0	783.94	125.02	169.79	80.22	102.15	118.69	81.64	111.47
Nov9/07	End1	0	2.68	0	623.46	88.23	159.15	80.25	61.23	101.82	81.34	110.49
	End2	0	0.32	0	623.99	88.56	159.47	80.21	60.84	101.94	81.36	110.6
	End3	0	0.32	0	624.47	88.56	159.54	80.2	61.48	101.89	81.37	110.73
Nov9/07	Start1	0	3.61	0	789.36	126.99	171.05	80.41	102.81	119.08	81.67	111.59
	Start2	0	3.48	0	785.98	126.27	170.54	80.4	102.44	118.71	81.62	111.34
	Start3	0	3.44	0	781.67	125.84	169.44	80.39	102.32	118.65	81.61	111.24
Nov14/07	End1	0	0.44	0	414.93	59.44	153.58	80.51	11.82	80.81	81.31	110.74
	End2	0	0.34	0	421.7	59.82	155.97	80.58	13.38	80.83	81.39	111.3
	End3	0	0.45	0	416.78	59.18	154.05	80.53	12.03	80.78	81.33	110.76
Nov14/07	Start1	0	3.53	0	781	124.95	168.65	79.86	101.47	118.13	81.59	111.34
	Start2	0	3.59	0	775.32	124.14	168.08	79.93	101.34	117.92	81.55	111.19
	Start3	0	3.45	0	768.31	122.19	166.98	79.79	101.05	117.58	81.46	110.78
Nov19/07	End1	0	0.35	0	300.99	38.22	146.97	79.27	2.28	0	80.29	108.86
	End2	0	0.38	0	301.15	38.52	139.9	79.28	0.94	0	80.31	108.75
	End3	0	0.3	0	300.21	38.54	139.83	79.3	0.38	0	80.26	108.62
Nov19/07	Start1	0	3.69	0	779.22	123.89	168.48	79.96	101.69	117.95	81.53	111.18
	Start2	0	3.95	0	768.18	123.22	167.49	80.02	100.81	117.58	81.51	110.78
	Start3	0	3.61	0	773.97	123.39	167.76	79.92	101.25	117.67	81.48	110.94
Nov23/07	End1	0	0.44	0	292.15	45.75	144.91	79.26	0.84	0	80.21	108.83
	End2	0	0.38	0	288.61	45.53	150.75	79.22	0.72	0	80.18	108.39
	End3	0	0.37	0	292.16	45.87	152.4	79.26	0.74	0	80.22	108.73
Nov23/07	Start1	0	3.69	0	760.72	122.9	167.29	80.23	100.28	117.47	81.46	110.34

	Start2	0	3.7	0	755.2	121.76	166.56	80.22	100.74	117.1	81.45	110.1
	Start3	0	3.66	0	755.56	122.13	166.31	80.2	100.26	117.18	81.44	109.96
Nov29/07	End1	0	0.3	0	261.81	13.42	138.47	77.94	0.17	0	79.2	106.65
	End2	0	0.26	0	261.82	13.35	139.29	77.92	1.28	0	79.21	106.75
	End3	0	0.33	0	262.7	13.7	132.03	77.95	0.15	0	79.21	106.85
Nov29/07	Start1	0	3.82	0	776.14	125.1	169.98	79.93	101.91	118.39	81.59	110.74
	Start2	0	3.78	0	775.36	125.26	169.69	79.95	101.64	118.31	81.59	110.71
	Start3	0	3.79	0	773.85	124.98	170.36	79.93	102.2	118.29	81.57	110.72
Dec4/07	End1	0	2.2	0	299.23	14.68	139.7	78.92	5.77	0	79.84	107.31
	End2	0	0.36	0	295.1	14.31	138.25	78.86	0.7	0	79.8	106.98
	End3	0	0.32	0	296.95	14.6	139.19	78.85	1.96	0	79.8	107.02
Dec4/07	Start1	0	3.78	0	781.87	124.73	169.24	79.81	101.56	118.09	81.58	111.45
	Start2	0	3.79	0	776.7	123.72	168.62	79.81	101.56	117.93	81.56	111.06
	Start3	0	3.68	0	774.17	124.16	168.32	79.78	101.63	117.89	81.55	111.03
Dec10/07	End1	0	0.3	0	292.97	0	111.6	77.79	1.54	0	79.17	105.62
	End2	0	2	0	293.13	0	112.05	77.81	1.99	0	79.21	105.87
	End3	0	0.3	0	292.85	0	111.86	77.84	4.75	0	79.19	105.71
Dec10/07	Start1	0	3.65	0	768.16	122.95	167.87	79.77	101	117.88	81.52	110.86
	Start2	0	3.63	0	771.55	123.99	168.22	79.81	101.32	117.92	81.55	110.76
	Start3	0	3.58	0	771.08	123.63	167.3	79.82	100.16	117.95	81.49	110.49
Dec14/07	End1	0	0.37	0	353.37	0	118.59	79.06	6.49	0	80.17	106.4
	End2	0	0.27	0	351.55	0	118.04	79.05	6.85	0	80.13	106.23
	End3	0	2.15	0	355.21	0	125.28	79.68	7.09	0	80.23	106.97
Dec14/07	Start1	0	3.48	0	746.94	120.31	164.59	79.41	99.98	116.83	81.39	109.82
	Srart2	0	3.55	0	744.96	120.25	164.31	79.47	99.02	116.57	81.36	109.63
	Start3	0	4.26	0	749.62	120.25	166.18	79.62	99.49	116.93	81.46	109.88
Dec19/07	End1	0	0.33	0	352.26	0	111.01	79.41	5.79	76.06	80.29	105.46
	End2	0	0.28	0	351.62	0	110.99	79.43	3.03	75.9	80.28	105.25
	End3	0	0.28	0	353.08	0	111.01	79.37	4.74	0	80.32	105.56
Dec19/07	Start1	0	3.59	0	770.27	123.8	168.78	79.81	101.34	118.02	81.57	110.69
	Start2	0	3.99	0	768.81	123.55	168.27	79.83	101.32	118.05	81.55	110.77
	Start3	0	3.7	0	772.05	125.15	169.19	79.91	102.31	118.43	81.58	110.8
Dec24/07	End1	0	0.27	0	398.2	0	138.22	81.28	3.22	76.71	80.96	108.43
	End2	0	0.35	0	395.75	0	138.25	81.12	3.74	76.65	80.94	108.8
	End3	0	0.36	0	397.51	0	138.44	81.11	2.97	76.69	80.98	108.79
Dec24/07	Start1	0	3.71	0	757.6	122.21	166.94	79.98	101.07	117.29	81.45	110.31
	Start2	0	3.73	0	758.19	122.05	166.56	79.95	100.28	117.46	81.44	110.32
	Start3	0	3.73	0	755.65	121.71	166.73	79.96	101.05	117.03	81.44	110.16
Dec28/07	End1	0	0.39	0	392.35	0	141.79	81.36	0.98	87.62	50.5	107.25
	End2	0	0.37	0	392.03	0	141.54	81.36	0.55	87.6	80.5	107.22
	End3	0	0.47	0	392.99	0	141.92	81.34	0.77	87.62	80.5	107.3
Dec28/07	Start1	0	3.62	0	766.85	123.49	168.59	80.03	101.89	118.13	81.59	110.47
	Start2	0	3.82	0	761.71	123.64	167.94	80.12	100.9	117.89	81.52	110.28
	Start3	0	3.62	0	761.34	123.44	167.92	80.03	101.61	117.89	81.53	110.36
Jan3/07	End1	0	0.41	0	408.67	9.61	139.31	80.77	1.08	92.3	80.34	107.76
	End2	0	0.41	0	408.55	10.01	132.87	80.77	1.18	92.3	80.34	107.69
	End3	0	0.47	0	408.15	9.65	138.95	80.79	0.83	92.3	80.34	107.72
Jan3/07	Start1	0	3.57	0	751.46	120.09	165.44	79.27	99.79	116.82	81.42	110.03

	Start2	0	3.6	0	749.02	120.12	164.71	79.29	99.96	116.65	81.38	110.04
	Start3	0	3.81	0	748.84	119.97	164.82	79.37	99.51	116.65	81.42	110.05
Jan8/07	End1	0	0.45	0	337.47	6	132.93	79.87	1.01	86	79.95	106.9
	End2	0	0.44	0	336.22	6.19	132.47	79.87	0.89	86.04	79.95	106.77
	End3	0	0.39	0	338.03	6.45	132.64	79.87	1.25	86.09	79.97	106.81
Jan8/07	Start1	0	3.59	0	721.9	118.67	162.45	79.41	98.28	115.9	81.3	108.43
	Start2	0	3.61	0	722.49	119.22	162.57	79.41	98.93	116.05	81.31	108.47
	Start3	0	3.57	0	722.52	118.71	162.53	79.34	98.52	115.79	81.3	108.44
Jan13/07	End1	0	0.49	0	252.49	0	118.55	79.57	0.95	81.59	79.5	104.78
	End2	0	0.39	0	252.81	0	118.41	79.62	1.55	81.59	79.54	104.67
	End3	0	0.42	0	252.71	3.25	118.43	79.59	1.85	81.64	79.53	104.78
Jan13/07	Start1	0	3.62	0	729.76	119.2	163.57	80.05	99.32	116.25	81.32	108.61
	Start2	0	3.62	0	722.24	118.5	162.34	80.06	98.48	115.84	81.28	108.38
	Start3	0	3.5	0	717.84	117.5	161.55	79.98	98.45	115.54	81.24	108.23
Jan18/07	End1	0	0.44	0	372.93	20.39	129.42	79.97	0.34	90.91	79.93	105.94
	End2	0	0.41	0	373.36	20.6	122.98	79.97	0.73	90.87	79.92	105.99
	End3	0	0.48	0	374.43	20.74	123.04	79.97	1.71	90.86	79.92	106.08