

# **Final Report**

## **Improving Nitrogen Recommendations for Potatoes Through Better Estimation of Determinacy**

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## **1. SUMMARY**

### **1.1. Aim**

The aim of this project was to develop some easily measured but reliable metrics that can be used by potato breeders, agronomists and others in the potato supply chain to allocate new potato varieties to their nitrogen (determinacy) grouping. This work is required because currently the conventional methods of determining nitrogen requirement relies on carrying out several, costly nitrogen response experiments. In consequence, it is likely that many new varieties have been misallocated to their nitrogen groups resulting in under-performance as a consequence of under or over-application of N.

### **1.2. Methodology**

The project will concentrate on three candidate metrics that previous work has shown could be used to place new varieties in their nitrogen groupings. These metrics are:

1. Integrated ground cover determined by weekly measurements of ground cover from emergence to canopy senescence. Indeterminate varieties (e.g. Group 4) tend to have more persistent canopies than determinate (Group 1) varieties and greater integrated ground covers.
2. Main-axis, above-ground nodes. Earlier studies have shown that counting the number of leaves on the mainstem and subsequent branches above each flower (sympodial branches) can discriminate between varieties with a larger or smaller N requirement for a given season length.
- 3 & 4. Harvest index measured at c. 55 days after emergence expressed in terms of either fresh weight (3) or dry weight (4). Experiments have shown that indeterminate varieties have smaller harvest indices (defined as tuber yield as a fraction of the tuber+ haulm yield) than determinate varieties.

In 2017-2019, experiments were done at NIAB, with Greenvale AP and Cygnet PB. These experiments tested different varietal mixtures and, due to experimental constraints, tested different candidate metrics. In addition to the new experiments, the project used historic data (particularly measurements of ground cover) that are derived from monitoring of both commercial and experimental crops.

### **1.3. Key findings**

Over three years, this program has shown that the four, candidate metrics are correlated with one another and can be used to determine the nitrogen grouping (and in turn the nitrogen requirement) of new potato varieties. The preferred metric is to count main-axis nodes on the potato plant since this method is robust, quick, cheap and non-destructive. However, when augmented with other metrics e.g. integrated ground cover and or harvest index, the accuracy of the node counting method is improved. Factors such as excess N, extremes of climates, poor soil condition will affect the reliability of these metrics but no more than they would affect the reliability of more traditional nitrogen response experiments.

### **1.4. Practical recommendations**

This research program has resulted in the development/publication of simple protocol that will enable stakeholders in varietal development and commercialisation to quickly determine the nitrogen grouping of new varieties.

## 2. INTRODUCTION

A key component of current nitrogen (N) fertilizer recommendations for potatoes is the determinacy group of the potato variety (AHDB 2017). A determinate variety is one that will cease leaf production after it has initiated its first flower and, conversely, an indeterminate variety will continue to produce tiers of leaves and flowers until curtailed by decreasing day length or frost. Varieties are placed in one of four groups ranging from Group 1 (very determinate, e.g. Accord, Estima and Innovator) to Group 4 (very indeterminate, e.g. Cara, Markies and Royal). For similar intended season length, a Group 1 variety typically needs about twice the amount of N as a Group 4 variety. The determinacy group of a new variety can be derived from the results of many N response experiments. In these experiments the effect of increasing N supply on canopy persistence and yield is measured in relation to control varieties of known, contrasting determinacy. This method is time-consuming and expensive and, in consequence, relatively few of the determinacy groups given in the *Nutrient Management Guide (RB209)* (AHDB 2017) are evidence-based. It is likely that many varieties are currently allocated determinacy groups on the basis of casual field observation and opinion. In recognition of this, in spring 2017 AHDB commissioned NIAB CUF to develop some easy-to-measure, objective metrics that could be used to reliably allocate varieties to determinacy groups without the need for extensive (and expensive) field experimentation.

Four candidate metrics will be studied:

1. Integrated ground cover. This is the area under the ground cover curve. Previous work has shown that determinate varieties tend to have smaller integrated ground covers than indeterminate varieties. The experimental data will be augmented by analysis of archived data (not reported here).
2. Harvest Index of fresh weight (FW) yield between haulm and tubers when measured at an early sampling (c. 50-60 days after emergence (DAE)). Previous work has shown that in experiments and when sampled at the same interval after emergence, indeterminate varieties have smaller harvest indices than determinate varieties, particularly at early samplings.
3. Harvest Index of dry weight (DW) yield. As above but based on the dry weight yield of haulm and tubers after being oven dried.
4. Main-axis, above-ground nodes. Earlier work (funded by CUPGRA) showed that the number of above ground nodes on the mainstem and sympodial branches was correlated with varietal determinacy (Allison *et al.* 2000).

To increase the experimental base that underpins the project, two industrial partners (Greenvale AP and Cygnet PB) agreed to supply data as an 'in-kind' contribution to the project.

### **3. MATERIALS AND METHODS**

In 2017, the experimental program comprised four field experiments: two at NIAB and one each at Cygnet PB and Greenvale AP. In 2018, the experimental program comprised four field experiments: two at NIAB and one each at Cygnet PB and Greenvale AP. Finally, in 2019, there were two experiments at NIAB and two with Greenvale AP. Although there was some varietal commonality, each experiment had a different varietal mix. Details of each experiment are given below.

#### **3.1. Determinacy Expt in NIAB Field 24 (2017)**

This experiment compared seven varieties (Cara, Estima, Infinity, Nectar, Soraya, Tyson and an unnamed clone 0751). Each variety was replicated five times and allocated at random to blocks. The experiment was planted by hand on 7 April into pre-formed ridges. Each plot was four rows (3 m) wide and 6 m long. Within-row spacing was 30 cm, giving an intended plant population of 44 400/ha. Immediately after planting, ammonium nitrate fertilizer was applied uniformly to each plot at a rate of 90 kg N/ha and shallowly incorporated by raking.

Crop emergence was measured every 3 – 4 days on the middle two rows of each plot from first emergence until no further plants emerged. Ground cover development was measured weekly on row 2 of each plot from c. 50 % plant emergence until final harvest. Integrated ground cover was calculated on a plot basis by linearly interpolating between the weekly measurements of ground cover to estimate the daily values and then summing. The experiment was sampled on 26 July (65 DAE) and 16 October (147 DAE). Sample areas were 3.15 m<sup>2</sup> (14 plants) and were taken from suitably guarded areas in each plot. For both samplings, the number of plants and mainstems was recorded and all tubers > 10 mm were collected. The tubers were graded in 10 mm increments and the number and weight of tubers in each grade was recorded. A sub-sample of tubers (a total of c. 1 kg from the grade(s) with the largest yield) was retained. The tuber sub-sample was washed, chipped and then oven-dried at 90 °C in a recirculating oven for a minimum of 48 hours to determine tuber dry matter concentration. At the first sampling, the haulm from each plot was retained, its total FW was weighed and then a sub-sample of c. 1 kg was retained for drying together with the tubers. Before the final sampling, main-axis above-ground nodes were counted in two, representative stems from each plot. An above ground node was counted if it contained a leaf > 5 mm long.

#### **3.2. Library Plots in NIAB Field 20 (2017)**

The principal role of the Library Plots is to provide material to train seed inspectors in varietal identification and in 2017 comprised 33 varieties (Accord, Arsenal, Brooke, Camel, Cara, Charlotte, Desiree, Electra, Estima, Eurostar, Fontane, Innovator, Jazzy, King Edward, Lady Claire, Lady Rosetta, Lanorma, Marfona, Maris Bard, Maris Peer, Maris Piper, Markies, Melody, Mozart, Nectar, Performer, Royal, Sagitta, Sapphire, Shelford, Taurus, VR808 and Wilja). Each plot was two rows (1.5 m) wide and 3 m long with no replication. The plots were machine-planted at c. 30 cm spacing on 3 April. Due to the diverse sources of seed material and delivery time to NIAB, varieties would have different extents of sprouting when planted and this is likely to impact on the interpretation of metrics collected. The experimental limitations of the Library Plots will be similar to those found in breeder's plots or when, during early commercialisation, seed supply is limited. Nitrogen fertilizer was applied at a rate of 200 kg N/ha. Plant emergence was only measured on 11 May, but ground covers were measured c. weekly using a grid from

c. 50 % emergence until the end of the season. At the end of the season main-axis above-ground nodes were measured on three representative stems from each plot.

### **3.3. Varietal Validation Experiment, Cygnet PB, Soham (2017)**

This experiment collected data from a subset of 13 varieties (Agria, Atlantic, Bambino, Cabaret, Chicago, Hermes, Lady Claire, Lady Rosetta, Maris Peer, Maris Piper, Markies, Saxon and Vizelle) from a much larger experiment of unnamed clones. Each variety was replicated three times and allocated at random to blocks. The experiment was planted on 7 and 8 May. Each plot comprised two rows with an average within-row spacing of 30.8 cm. Plot length was c. 2.2 m and between-row spacing was 0.914 m. A total of 368 kg N/ha was applied to the experimental area. Emergence was measured every 2 to 5 days from first emergence until there was no further increase in emergence. Ground cover was measured c. weekly from a few days after 50 % emergence until mid-September. Main-axis, above-ground nodes > 5 mm were recorded in two, representative stems from each plot towards the end of the season when leaf production had slowed or stopped.

### **3.4. Varietal Attribute Trial, Greenvale AP, Lowestoft (2017)**

This experiment tested five varieties (Estima, Red Fantasy, Soraya, Tyson and the unnamed clone 0751). The experiment was planted on 26 April at an average spacing of 27 cm into rows with 0.965 m centres to give a target plant population of 38 372/ha. Each variety was replicated three times and allocated at random blocks. The experiment received a total of 220 kg N/ha as a pre-planting and post-emergence dressing. Emergence was measured every 3 or 4 days from first emergence until no further plants emerged. Ground cover development was measured weekly from c. 50 % emergence until the end of September. The crop was sampled on 18 July (54 DAE) and 22 September (120 DAE). At each harvest, sample areas of 2.61 m<sup>2</sup> (10 plants) were taken. Samples were processed and data recorded in a similar way to the Determinacy experiment at NIAB CUF. At the first sampling, haulm FW and DW yields were recorded so that the harvest indices could be calculated. Towards the end of the season, the number of mainstem above ground nodes > 5 mm was recorded on two representative stems per plot.

### **3.5. Determinacy Expt in NIAB Field 29 (2018)**

This experiment compared seven varieties (Cara, Estima, Infinity, Nectar, Red Fantasy, Soraya and Tyson). Each variety was replicated five times and allocated at random to blocks. The experiment was planted by hand on 24 April into pre-formed ridges. Each plot was four rows (3 m) wide and 6 m long. Within-row spacing was 30 cm, giving an intended plant population of 44 400/ha. Immediately after planting, ammonium nitrate fertiliser was applied uniformly to each plot at a rate of 80 kg N/ha and shallowly incorporated by raking.

Crop emergence was measured every 3–4 days on the middle two rows of each plot from first emergence until no further plants emerged. Ground cover development was measured weekly on row 2 of each plot from c. 50 % plant emergence until final harvest. Integrated ground cover was calculated on a plot basis by linearly interpolating between the weekly measurements of ground cover to estimate the daily values and then summing. The experiment was sampled on 19 July (c. 55 DAE) and 16 October (c. 144 DAE). Sample areas were 3.15 m<sup>2</sup> (14 plants) and were taken from suitably guarded areas in each plot. For both samplings, the number of plants and mainstems was recorded and all tubers > 10 mm were collected. The tubers were graded in 10 mm increments and the number and weight of tubers in each grade was recorded. A sub-sample of tubers (a total of c. 1 kg from the grade(s) with the largest yield) was retained. The

tuber sub-sample was washed, chipped and then oven-dried at 90 °C in a recirculating oven for a minimum of 48 hours to determine tuber dry matter concentration. At the first sampling, the haulm from each plot was retained, its total FW was weighed and recorded and then a sub-sample of c. 1 kg was retained for drying together with the tubers. Once the canopies of each plot had senesced to c. 50 % the number of main-axis above-ground nodes were counted in two, representative stems from each plot. A node was counted if it contained a leaf > 5 mm long.

### **3.6. Library Plots in NIAB Field 29 (2018)**

The principal role of the Library Plots is to provide material to train seed inspectors in varietal identification and in 2018 comprised 27 varieties (Agria, Brooke, Cabaret, Cara, Charlotte, Cultra, Desiree, Estima, Harmony, Hermes, Innovator, King Edward, Lady Claire, Lady Rosetta, Lanorma, Marfona, Maris Peer, Maris Piper, Markies, Melody, Nectar, Pentland Dell, Rooster, Royal, Russet Burbank, Sagitta and Taurus). Each plot was three rows (2.25 m) wide and 3 m long and there was no replication. The plots were machine-planted at c. 30 cm spacing on 26 April. Due to the diverse sources of seed material and delivery time to NIAB, varieties would have different extents of sprouting when planted and this is likely to impact on the interpretation of metrics collected. The experimental limitations of the Library Plots will be similar to those found in breeder's plots or when, during early commercialisation, seed supply is limited. Nitrogen fertiliser was applied at a rate of 200 kg N/ha. The course of plant emergence was only measured on three occasions and ground covers were measured c. weekly using a grid from c. 50 % emergence until the end of the season. At the end of the season, once canopies had senesced to < 50 % ground cover, main-axis above-ground nodes were measured on three representative stems from each plot.

### **3.7. Varietal Validation Experiment, Cygnet PB, Soham (2018)**

This experiment collected data from 14 varieties (Atlantic, Bambino, Cabaret, Cara, Chicago, Estima, Hermes, Lady Claire, Lady Rosetta, Maris Peer, Maris Piper, Markies, Saxon and Vizelle) and was located near Soham, Cambridgeshire (N52.3480 E0.3657). Each variety was replicated three times and allocated at random to blocks. The experiment was planted on 14 May. Each plot comprised two rows with an average within-row spacing of 30.8 cm. Plot length was c. 2.2 m and between-row spacing was 0.914 m. Ground cover was measured c. weekly from a few days after 50 % emergence until mid-September. Main-axis, above-ground nodes > 5 mm were recorded in three, representative stems from each plot towards the end of the season when canopies had senesced to c. 50 % ground cover.

### **3.8. Varietal Attribute Trial, Greenvale AP, Somerleyton (2018)**

The 2018 experiment was done at Somerleyton, Suffolk (N52.5122, E1.6720) and tested six varieties (Estima, Jelly, Soraya, Tyson and two unnamed clones: 11.Z.114.A9 and 11.Z.114.A19). The experiment was planted on 25 April at an average spacing of 25 cm into rows with 0.965 m centres to give a target plant population of 41 450/ha. Each variety was replicated three times and allocated at random to blocks. The experiment received a total of 200 kg N/ha as a pre-planting and post-emergence dressing. Emergence was measured every 3 or 4 days from first emergence until no further plants emerged. Ground cover development was measured weekly from c. 50 % emergence until the end of September. The crop was sampled on 19 July (55 DAE) and 17 September (115 DAE). At each harvest, sample areas of 1.93 m<sup>2</sup> (8 plants) were taken. Samples were processed and data recorded in a similar way to the Determinacy Experiment at NIAB CUF. At the first sampling, haulm FW and DW yields were recorded so that the harvest indices could be calculated. Towards the end of the season, the

number of mainstem above-ground nodes > 5 mm was recorded on two representative stems per plot.

### **3.9. Determinacy Expt in NIAB Field 30 (2019)**

This experiment compared seven varieties (Cara, Estima, Molly, Nectar, Soraya, Tyson and an unnamed variety "A13"). Each variety was replicated five times and allocated at random to blocks. The experiment was planted by hand on 16 April into pre-formed ridges. Each plot was four rows (3 m) wide and 6 m long. Within-row spacing was 30 cm, giving an intended plant population of 44 400/ha. Nitrogen was applied post-planting onto ridges on 30 April at a rate of 80 kg/ha.

Crop emergence was measured every 3–4 days on the middle two rows of each plot from first emergence until no further plants emerged. Ground cover development was measured weekly on row 2 of each plot from c. 50 % plant emergence until final harvest. Integrated ground cover was calculated on a plot basis by linearly interpolating between the weekly measurements of ground cover to estimate the daily values and then summing. The experiment was sampled on 8 July (c. 49 DAE) and 8 October (c. 141 DAE). Sample areas were 3.15 m<sup>2</sup> (14 plants) and were taken from suitably guarded areas in each plot. For both samplings, the number of plants and mainstems was recorded and all tubers > 10 mm were collected. The tubers were graded in 10 mm increments and the number and weight of tubers in each grade was recorded. A sub-sample of tubers (a total of c. 1 kg from the grade(s) with the largest yield) was retained. The tuber sub-sample was washed, chipped and then oven-dried at 90 °C in a recirculating oven for a minimum of 48 hours to determine tuber dry matter concentration. At the first sampling, the haulm from each plot was retained, its total FW was weighed and recorded and then a sub-sample of c. 1 kg was retained for drying together with the tubers. Once the canopies of each plot had senesced to c. 50 % the number of main-axis above-ground nodes were counted in two, representative stems from each plot. A node was counted if it contained a leaf > 5 mm long.

### **3.10. Library Plots in NIAB Field 30 (2019)**

The principal role of the Library Plots is to provide material to train seed inspectors in varietal identification and in 2019 comprised 27 varieties (Agria, Brooke, Cabaret, Cara, Charlotte, Cultra, Desiree, Estima, Harmony, Hermes, Innovator, King Edward, Lady Claire, Lady Rosetta, Lanorma, Marfona, Maris Peer, Maris Piper, Markies, Melody, Nectar, Pentland Dell, Rooster, Royal, Russet Burbank, Sagitta and Taurus). Each plot was three rows (2.25 m) wide and 3 m long and there was no replication. The plots were machine-planted at c. 30 cm spacing on 15 April. Due to the diverse sources of seed material and delivery time to NIAB, varieties would have different extents of sprouting when planted and this is likely to impact on the interpretation of metrics collected. The experimental limitations of the Library Plots will be similar to those found in breeder's plots or when, during early commercialisation, seed supply is limited. Nitrogen fertilizer was applied at a rate of 200 kg N/ha. The course of plant emergence was measured every 3 to 4 days and ground covers were measured c. weekly using a grid from c. 50 % emergence until the end of the season. At the end of the season, once canopies had senesced to < 50 % ground cover, main-axis above-ground nodes were measured on three representative stems from each plot.

### **3.11. Varietal Attribute Trial, Greenvale AP, Icklingham (2019)**

In 2019, two experiments were done near Icklingham, Suffolk (N52.3411, E0.5870) and both tested five varieties (Estima, Jelly, Tyson and two unnamed clones: 11.Z.114.A9 and 11.Z.114.A19). One experiment used a "Low" rate of N (192 kg N/ha) and the other a "High"

rate (266 kg N/ha). Both experiments were planted on 19 April at an average spacing of 26 cm into rows with 0.9144 m centres to give a target plant population of 42 062/ha. Each variety was replicated four times and allocated at random to blocks. The N was applied as a pre-planting and post-emergence dressing. Emergence was measured every 3 or 4 days from first emergence until no further plants emerged. Ground cover development was measured weekly from c. 50 % emergence until the end of September. The crop was sampled on 8 July (51 DAE) and 4 September (109 DAE). At each harvest, sample areas of 1.90 m<sup>2</sup> (8 plants) were taken. Samples were processed and data recorded in a similar way to the Determinacy experiment at NIAB CUF. At the first sampling, haulm FW and DW yields were recorded so that the harvest indices could be calculated. Towards the end of the season, the number of mainstem above ground nodes > 5 mm was recorded on two representative stems per plot.

### **3.12. Statistical analysis**

The candidate metrics of harvest index, integrated ground cover and main axis above ground nodes are continuous variables. To be of use in decision support system (e.g. the Nutrient Management Guide), these metrics need to be converted to integer values of 1, 2, 3 or 4 corresponding to the determinacy group of the variety. To do this a procedure similar to that used in Independent Variety Testing (IVT, see for example Campbell et. al 2017) was employed. Initially, the varietal determinacy scale was also assumed to be a continuous variable with values ranging from  $\geq 1$  to  $< 5$ . The candidate metrics were then converted to the varietal determinacy scale using two extreme control varieties in each experiment. Once linearized, these values were rounded down to the integer value.

For the experiments at NIAB and Cygnet, the control varieties were Estima and Cara and these were assumed to have determinacy values 1 and 4, respectively. For the experiment with Greenvale AP, the control varieties were Estima (1), Jelly (3) or Red Fantasy (3). For the two experiment at Cygnet the control varieties were Lady Claire (2) and Markies (4) or Estima (1) and Cara (4).

Variates were analysed by analysis of variance (ANOVA) and results are described as significantly different if the chances of those differences occurring by chance are less than 5 % ( $P = 0.05$ ). In conjunction with ANOVA, metrics of determinacy were also analysed using Fisher's protected least significance test (F-PLSD) which facilitates the grouping of varieties with similar characteristics. In this test, varietal means that are significantly different are suffixed with different letters.

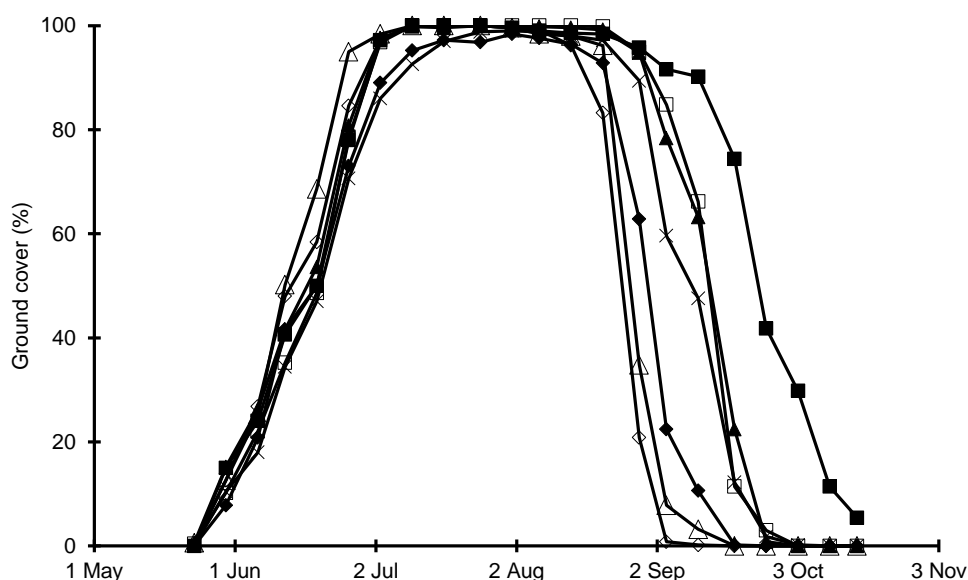
## 4. RESULTS AND DISCUSSION

### 4.1. Determinacy Expt in NIAB Field 24 (2017)

#### 4.1.1. Emergence and ground cover development

The date of 50 % emergence for the seven varieties was fairly similar and ranged from 21 May (Infinity) to 25 May (Estima) and averaged 22 May (45 days after planting). Complete or near-complete emergence was obtained in each plot. The pattern of ground cover development is shown in **Figure 1**. As the canopies expanded, Tyson achieved 50 % ground cover 21 DAE compared with 27 DAE for Nectar and 0751. With the exception of Estima, all varieties achieved 100 % ground cover. The most persistent canopy was Cara (101 days from 50 % ground cover as the canopy expanded in the spring to 50 % ground cover as it senesced in the autumn). The least persistent canopies were Tyson, Estima and Soraya (76, 75 and 72 days, respectively).

**Figure 1.** Development of ground cover in Determinacy Experiment NIAB CUF. Cara, ■; Estima, ◆; Infinity, ▲; Nectar, □; Soraya, ◇; Tyson, △ and 0751, x.



#### 4.1.2. Yield at the first and second samplings

At the first crop sample stem, populations ranged from 103 000/ha in Tyson to 198 000/ha in Cara (**Table 1**). Despite having the largest stem population, Cara had the smallest tuber population (341 000), whilst infinity had the largest (575 000/ha). Total tuber FW yields averaged 32.9 t/ha and ranged from 18.6 t/ha (Cara) to 42.1 t/ha (Estima). Tuber DM concentrations ranged from 16.6 % (Cara and 0751) to 21.5 % (Infinity). At the second sampling, stem populations were similar to those found at the earlier sampling and had a mean value of 150 000/ha (**Table 2**). The mean, total tuber population was 450 000/ha. Although the mean value was similar to that found at 65 DAE, tuber populations had increased in some varieties (e.g. Nectar) and decreased in others (e.g. 0751). Between the two harvests, mean total FW yields increased from 32.9 to 57.7 t/ha. The smallest total FW yield was produced by Tyson (55.3 t/ha) and the largest by Estima and Infinity (both 62.2 t/ha). However, the tuber DM concentration of Infinity was much greater than that of Estima (**Table 2**).

**Table 1. Components of yield on 26 July (65 DAE) in the Determinacy Experiment at NIAB F24 in 2017**

Variety	Plant population (000/ha)	Stem population (000/ha)	Total tuber population (000/ha)	Total tuber yield (t FW/ha)	Tuber DM concentration (%)
Cara	44.4	198	341	18.6	16.6
Estima	44.4	121	452	42.1	18.7
Infinity	43.8	162	575	34.5	21.5
Nectar	44.4	166	545	25.7	17.1
Soraya	44.4	151	483	41.5	17.2
Tyson	44.4	103	418	36.3	17.3
0751	44.4	137	420	32.0	16.6
Mean	44.3	148	462	32.9	17.9
S.E. (24 D.F.)	0.23	7.7	26.7	1.59	0.53

**Table 2. Components of yield on 16 October (147 DAE) in the Determinacy Experiment at NIAB F24 in 2017**

Variety	Plant population (000/ha)	Stem population (000/ha)	Total tuber population (000/ha)	Total tuber yield (t FW/ha)	Tuber DM concentration (%)
Cara	44.4	196	402	54.9	22.1
Estima	44.4	112	418	62.2	21.0
Infinity	44.4	170	523	62.2	27.0
Nectar	44.4	195	618	58.8	20.4
Soraya	44.4	152	469	60.4	18.7
Tyson	44.4	102	372	49.8	21.5
0751	44.4	123	352	55.3	19.6
Mean	44.4	150	450	57.7	21.5
S.E. (24 D.F.)	-	17.1	18.1	2.43	0.33

#### 4.1.3. Metrics of determinacy

**Table 3** summarises the metrics of determinacy for the seven varieties. In general, there was agreement between the metrics. For example, Cara had the largest integrated ground cover, the smallest FW and DW harvest index and the most main-axis above-ground nodes. Conversely, Estima, Soraya and Tyson had small values for integrated ground cover. Estima also had the largest FW and DW harvest index and together with Soraya, Infinity and 0751 had the fewest main-axis leaves. The metrics based on FW and DW harvest index separated the varieties in a similar way suggesting that FW harvest index could be used if there was no access to a drying oven.

**Table 3. Metrics of determinacy in the Determinacy Experiment at NIAB F24 in 2017**

Variety	Integrated ground cover (% days)	FW harvest index at H1 (%)	DW harvest index at H1 (%)	Main axis above ground nodes (No.)
Cara	10139 d*	25.5 a	30.5 a	31.9 e
Estima	7373 a	63.3 d	68.3 d	20.5 ab
Infinity	8944 c	49.5 c	56.8 c	22.4 bc
Nectar	8791 c	37.8 b	43.3 b	26.2 d
Soraya	7202 a	62.4 d	67.4 d	19.6 a
Tyson	7630 a	51.6 c	58.5 c	23.3 c
0751	8139 b	50.0 c	54.8 c	22.2 bc
Mean	8317	48.4	54.2	23.7
S.E. (24 D.F.)	166.7	1.25	1.91	0.85

\* values with different letters are significantly different from one another at  $P < 0.05$ .

## 4.2. Library Plots in NIAB Field 20 (2017)

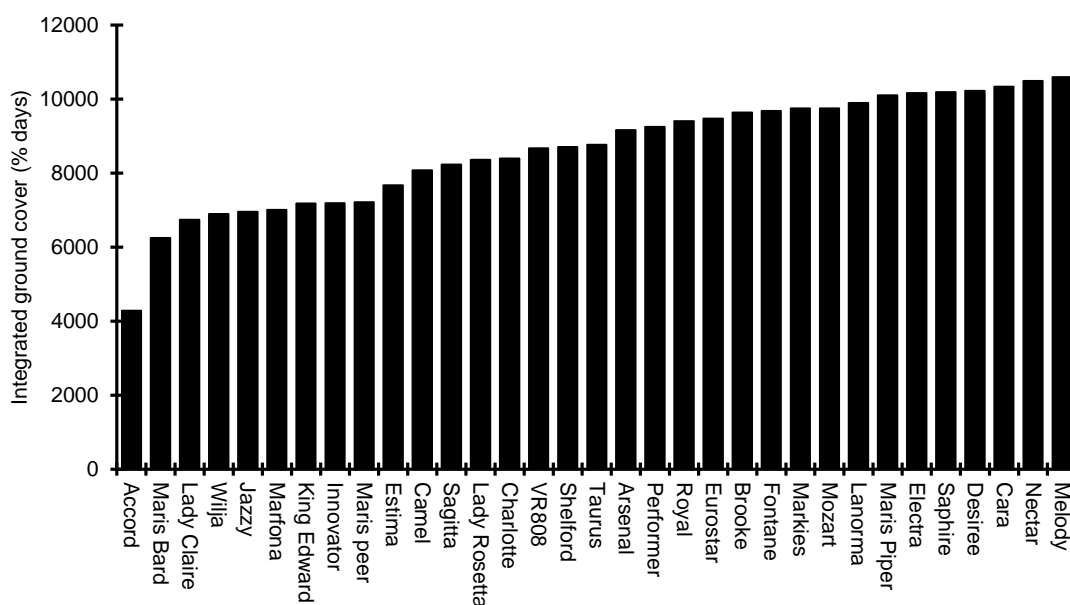
### 4.2.1. Emergence and ground cover

Based on the single measurement of crop emergence and subsequent ground cover development, the average date of 50 % emergence was estimated as c. 15 May. On the basis of ground cover development, it is likely that some varieties emerged relatively early (e.g. Cara) and some relatively late (Camel, Electra and Mozart). It is possible that this c. 2 week range in emergence date may have been due to variable sprouting between the varieties. With the exception of Accord, which had a maximum GC of 67 %, all varieties attained ground covers > 90 % and the majority attained complete cover. At the final GC assessment, ground covers ranged from 100 % (Cara) to 0 % (e.g. Estima, Lady Rosetta and Marfona).

### 4.2.2. Metrics of determinacy

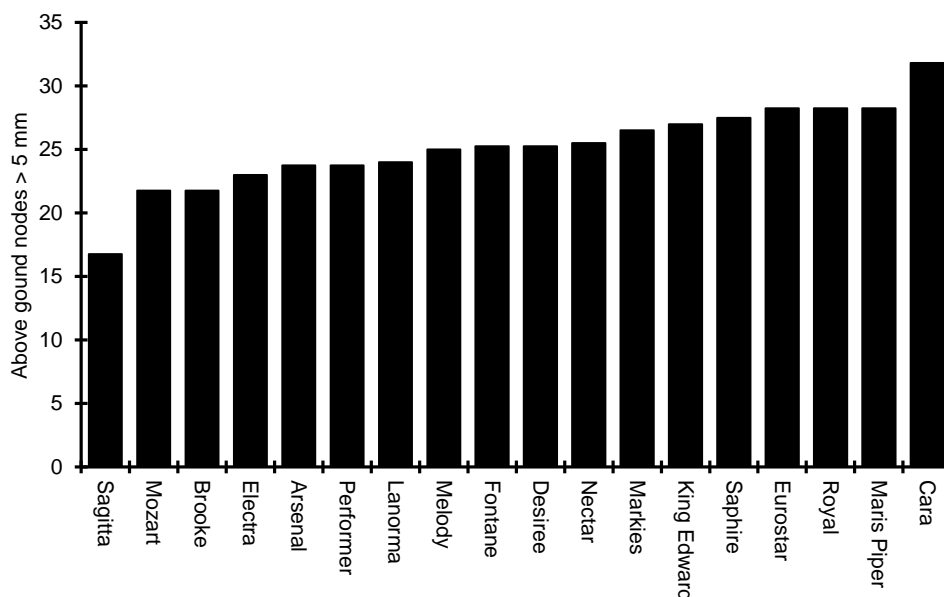
Due to the design of the Library plots (small, two-row, unreplicated (with the exception of Cara) plots that were primarily used for demonstrating varietal difference) it was not appropriate to sample the crops mid-season to measure FW and DW harvest index. The ranking of the varieties by integrated ground cover is shown in Figure 7. Cara (Determinacy Group 4) tended to have one of the more persistent canopies as did Nectar (as found in the replicated Determinacy experiment). Melody had a large canopy, but this may have been a consequence of its nearest neighbours (Estima and Taurus) being relatively short-lived and thus not providing much competition. At the other extreme, Accord (Determinacy Group 1) had the shortest-lived canopy as did Maris Bard (Determinacy Group 1). However, King Edward (Determinacy Group 3) was also placed toward the determinate end of the scale when using the metric of canopy persistence.

**Figure 2. Integrated ground cover for the 33 varieties in the NIAB Library plots in F20 2017.**



Since some of the canopies were almost completely senesced at the time of sampling, mainstem above-ground node data were obtained for only 18 of the 33 varieties (**Figure 3**). It is likely that since they had persistent canopies, most of the varieties where node data were obtained were probably Determinacy Group 3 or 4. Known Group 4 varieties (e.g. Cara and Royal) tended to have more main-axis nodes than other varieties although Maris Piper (Group 3) had the second largest number of main-axis nodes.

**Figure 3. Number of main axis above ground nodes in the NIAB Library Plots in F20 2017.**

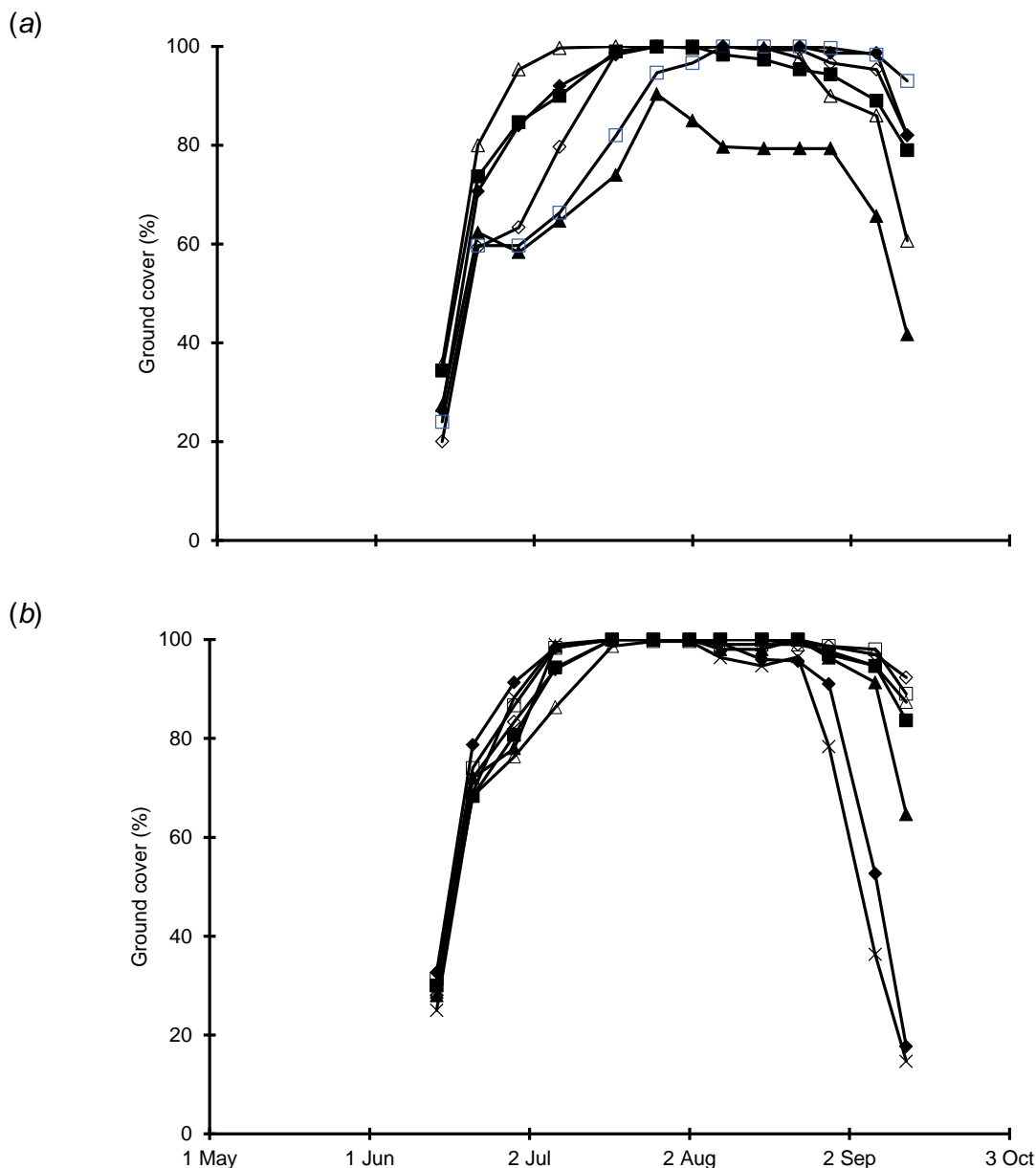


### **4.3. Varietal Validation Experiment, Cygnet PB, Soham (2017)**

#### **4.3.1. Emergence and ground cover development**

For the 13 varieties tested, the average date of 50 % emergence was 28 May and 50 % emergence ranged from 26 May (Maris Peer) to 1 June (Markies). All plots achieved complete or near-complete emergence. Development of ground cover is shown in **Figure 4a and b**. The average, maximum rate of canopy expansion was 4.2% per day. Lady Claire, Hermes, Vizelle and Markies had more rapid rates of canopy expansion (5.8, 5.8, 5.5 and 5.1 %/day, respectively), whilst varieties such as Bambino and Chicago were much slower (2.0 and 2.1 %/day, respectively). On average, 50 % ground cover was achieved on 19 June c. 3 weeks after 50 % emergence. With the exception of Bambino, all varieties achieved complete ground cover. Some varieties (e.g. Agria, Cabaret, Chicago, Lady Rosetta, Maris Piper, Markies and Saxon) still had ground covers > 80 % when the final GC measurement was made on 13 September and for these varieties it is not possible to accurately estimate canopy persistence. Vizelle, Lady Clair and Bambino all had canopy durations of < 90 days.

**Figure 4. Ground cover development in the Cygnet PB Varietal Validation Experiment. a):** Agria, ■; Atlantic, ◆; Bambino, ▲; Cabaret, ◇; Chicago, □ and Hermes, △. **b):** Lady Claire, ■; Lady Rosetta, ◆; Maris Peer, ▲; Maris Piper, ◇; Markies, □; Saxon, △ and Vizelle, x.



#### 4.3.2. Metrics of determinacy

Owing to the small plot size it was not possible to take an early sample to measure varietal difference in partitioning of DM between haulm and tubers. Varietal differences in integrated ground cover and above-ground nodes are shown in **Table 4**. The integrated ground cover data should be treated with caution since, as noted above, several varieties still had substantial ground covers when the last observation was made. The data indicate that there were some correlations between main-axis nodes and integrated ground cover, but there were also some exceptions. For example, Chicago had the largest number of above ground nodes (28.0) but a relatively small integrated ground cover (7948 % days). Conversely, Lady Claire had relatively few main-axis nodes (20.2) but had a relatively persistent canopy (8139 % days). For Chicago, the discrepancy may be due to it having poor canopy expansion at the start of the season and the observations stopping too early to measure canopy persistence. For Lady Claire, the

persistent canopy may be a consequence of the large N dressing (> 300 kg N/ha) applied to the trial site.

**Table 4. Metrics of determinacy in the Cygnet PB Varietal Validation Experiment in 2017**

Variety	Integrated ground cover (% days)	Main axis above ground nodes (No)
Agria	8534 cd*	23.8 bc
Atlantic	8540 cd	20.2 a
Bambino	6740 a	23.0 bc
Cabaret	8091 bcd	23.3 bc
Chicago	7948 bc	28.0 e
Hermes	8687 d	23.0 bc
Lady Claire	8139 bcd	20.2 a
Lady Rosetta	8594 cd	25.2 cd
Maris Peer	8491 cd	24.0 bc
Maris Piper	8644 d	27.0 de
Markies	8744 d	23.2 bc
Saxon	8422 bcd	21.3 ab
Vizelle	7693 b	21.7 ab
Mean	8244	23.4
S.E.	256.9	0.93

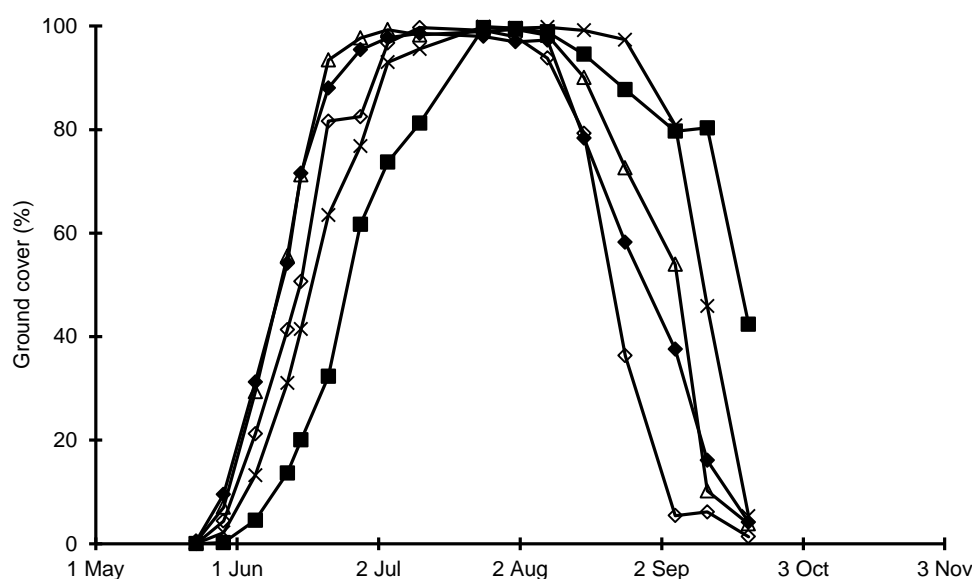
\* values with different letters are significantly different from one another at P < 0.05.

#### 4.4. Varietal Attribute Trial, Greenvale AP, Lowestoft (2017)

##### 4.4.1. Emergence and ground cover development

The mean date of achieving 50 % plant emergence was 25 May and ranged from 22 May (Tyson) to 31 May (Red Fantasy). Most varieties achieved complete or near-complete emergence, with the exception of Red Fantasy which achieved only c. 70 % of that intended. The development of ground cover is shown in **Figure 5**. The shortest interval between 50 % plant emergence and attaining 50 % ground cover was 19 days for Estima and Soraya compared with 27 days for Red Fantasy. The slow canopy expansion in Red Fantasy was probably due to the large number of missing plants. All the varieties produced complete or near-complete canopies. The interval between 50 % GC in the expanding canopy and 50 % in the senescing canopy ranged from 69 days (Soraya) to 86 days in the unnamed clone, 0751.

**Figure 5. Development of ground cover in the Greenvale AP Variety Attribute Experiment. Red Fantasy, ■; Estima, ◆; Soraya, ◇; Tyson, △ and 0751 x.**



#### 4.4.2. Yield at the first and second samplings

At the first sampling the mainstem populations averaged 121 000/ha and ranged from 78 000/ha (Tyson) to 189 000 Estima (**Table 5**). Despite having the smallest stem population, Tyson had the greatest maximum rate of canopy expansion (5.0 %/day) compared with an average of 4.3 %/day. Tuber populations showed a two-fold variation from 223 000/ha in Red Fantasy to 447 000/ha in Estima. At 54 DAE, the mean tuber yield was 35 t/ha, but there was considerable variation from 18.8 t/ha in Red Fantasy to 42.7 t/ha in Estima. Estima also had the greatest tuber DM concentration (17.3 %) whereas 0751 had the smallest (14.2 %).

**Table 5. Components of yield on 18 July (54 DAE) in GvAP Variety Attribute Experiment in 2017**

Variety	Plant population (000/ha)	Stem population (0000/ha)	Total tuber population (1000/ha)	Total tuber yield (t FW/ha)	Tuber DM concentration (%)
Estima	38.4	189	447	42.7	17.3
Red Fantasy	37.1	114	223	18.8	15.1
Soraya	38.4	131	440	39.2	14.9
Tyson	38.4	78	336	38.0	14.9
0751	38.4	95	366	36.3	14.2
Mean	38.1	121	362	35.0	15.3
S.E. (8 D.F.)	0.58	5.0	27.4	2.54	0.10

Numerically, stem populations were slightly smaller for all varieties at the second when compared with the first harvest (**Table 6**). Conversely, on average, tuber populations were slightly larger at the second harvest than at the first, with the largest numeric increase occurring in Soraya where the population increased from 440 000 to 504 000/ha. Between the first and second samplings, average tuber FW yield increased from 35.0 to 75.2 t/ha. Whilst there were some numeric differences in FW yield between varieties, these differences were not statistically significant (**Table 6**).

**Table 6. Components of yield on 22 September (120 DAE) in the GVAP Variety Attribute Experiment in 2017**

Variety	Plant population (000/ha)	Stem population (000/ha)	Total tuber population (000/ha)	Total tuber yield (t FW/ha)	Tuber DM concentration (%)
Estima	38.4	160	430	78.9	19.2
Red Fantasy	35.8	96	281	70.5	20.0
Soraya	38.4	108	504	83.1	17.3
Tyson	35.8	79	340	71.3	19.0
0751	38.4	92	339	72.4	18.2
Mean	37.4	107	379	75.2	18.9
S.E. (8 D.F.)	1.22	10.7	23.8	5.05	0.74

#### 4.4.3. Metrics of determinacy

**Table 7** shows candidate determinacy metrics derived from measurement of ground cover, sample data or from non-destructive counting of above-ground, main-axis nodes. Despite some visual difference in the pattern of ground cover development, there were no significant differences in integrated ground cover and therefore, in this experiment, this metric did not differentiate the varieties. As found in the Determinacy Experiment at NIAB, both the FW and DW harvest index sorted the varieties into similar groups with Estima being at one extreme and Red Fantasy at the other. From the harvest index data, it also appeared that Tyson was more indeterminate than either Soraya or 0751. Despite the harvest index data suggesting that Estima and Red Fantasy were quite different in how they allocated DM, these two varieties could not be separated by main-axis node data.

**Table 7. Metrics of determinacy for the GVAP Variety Attribute Experiment in 2017**

Variety	Integrated ground cover (% days)	FW harvest index at H1 (%)	DW harvest index at H1 (%)	Main axis above ground nodes (No.)
Estima	7913 a	62.1 d	73.8 d	21.0 a
Red Fantasy	7874 a	25.2 a	34.0 a	22.7 ab
Soraya	6920 a	51.6 c	61.7 c	21.8 a
Tyson	8323 a	40.8 b	50.8 b	25.0 b
0751	8398 a	53.6 c	61.3 c	25.3 b
Mean	7886	46.6	56.3	23.2
S.E. (8 D.F.)	376.6	1.38	1.96	0.85

\* values with different letters are significantly different from one another at  $P < 0.05$

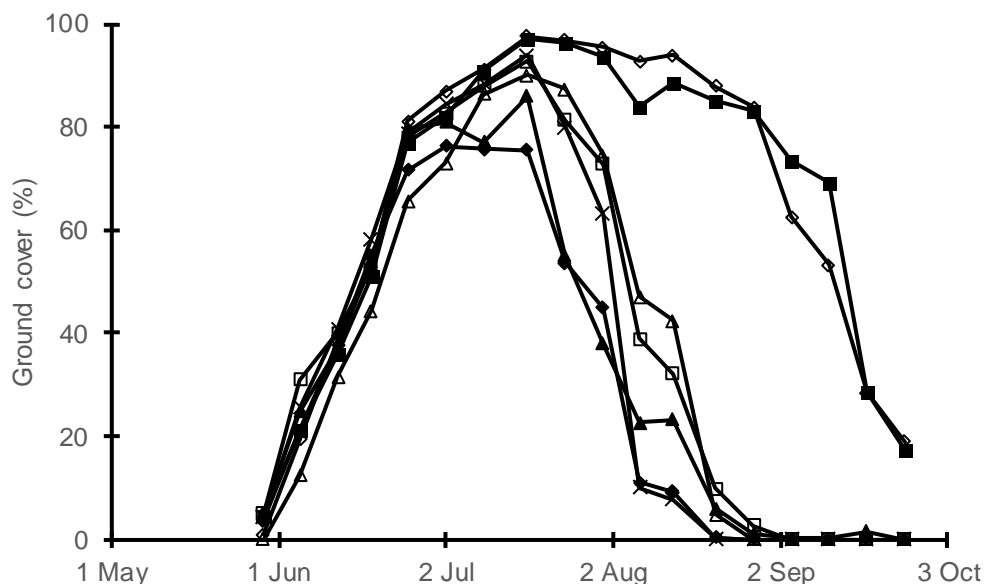
## 4.5. Determinacy Expt in NIAB Field 29 (2018)

### 4.5.1. Emergence and ground cover development

The date of 50% emergence for the seven varieties ranged from 22 May (Cara) to 30 May (Red Fantasy). For all varieties, the average date of 50 % emergence was 24 May (c. 30 days after planting) which was similar to the date recorded in 2017 despite the 2018 experiment being planted 17 days later than the experiment in 2017. However, when compared with 2017 where all varieties achieved near complete ground cover, ground cover development was poor in 2018. Red Fantasy and Cara achieved the largest ground covers (98 and 97 %, respectively) whilst Estima and Infinity attained only 76 and 86 %, respectively. The pattern of ground cover development is shown in **Figure 6**. As the canopies expanded, Red Fantasy achieved 50 % ground cover at 19 DAE compared with 27 DAE for Cara and 25 DAE for Estima and Nectar.

The most persistent canopies were Cara and Red Fantasy (89 and 87 days from 50 % ground cover as the canopy expanded in the spring, to 50 % ground cover as it senesced in the autumn, respectively). The least persistent canopies were those of Infinity, Estima, Soraya and Tyson (40, 41, and 48 days, respectively).

**Figure 6. Development of ground cover in the Determinacy Experiment NIAB. Cara, ■; Estima, ◆; Infinity, ▲; Nectar, □; Red Fantasy, ◇; Soraya, △ and Tyson, x.**



#### 4.5.2. Yield at the first and second samplings

Although emergence and initial ground cover development was rapid, plant establishment was relatively poor when compared with the experiment in 2017 and most plots had at least one or two missing plants. This was most noticeable in Red Fantasy, where the average achieved population was considerably less than the intended (36 200 compared with 44 400, **Table 8**). At the first crop sampling, stem populations ranged from 62 000/ha in Soraya to 225 000/ha in Nectar (**Table 8**). Soraya also had the smallest tuber population (324 000/ha) and Nectar the largest (771 000/ha). Total tuber FW yields averaged 30.9 t/ha and ranged from 25.4 t/ha (Cara) to 36.8 t/ha (Estima) and tuber DM concentrations ranged from 19.0 % (Cara and Soraya) to 22.0 % (Infinity) with an average of 20.4 %. At the second sampling, stem populations were broadly similar to those found at the initial sampling and had a mean value of 110 000/ha (**Table 9**) and the mean, total tuber population was 463 000/ha. Between the two harvests, mean total FW yields increased from 30.9 to 48.9 t/ha. The smallest total FW yield was produced by Estima (40.7 t/ha) and, as a consequence of their more persistent canopies, the largest yields were produced by Red Fantasy (56.9 t/ha) and Cara (58.0 t/ha). Soraya had the smallest tuber dry matter concentration (19.0 %) and Infinity the largest (23.4 %).

**Table 8. Components of yield on 19 July (55 DAE) in the Determinacy Experiment at NIAB F29 in 2018**

Variety	Plant population (000/ha)	Stem population (000/ha)	Total tuber population (000/ha)	Total tuber yield (t FW/ha)	Tuber DM concentration (%)
Cara	43.8	116	421	25.4	19.0
Estima	43.8	81	399	33.2	20.6
Infinity	43.8	93	450	30.2	22.0
Nectar	43.8	225	771	36.8	21.2
Red Fantasy	36.2	166	467	26.7	19.5
Soraya	43.2	62	324	32.2	19.1
Tyson	43.8	68	401	31.6	21.2
Mean	42.6	116	462	30.9	20.4
S.E. (24 D.F.)	1.09	8.6	23.6	1.09	0.26

**Table 9. Components of yield on 16 October (144 DAE) in the Determinacy Experiment at NIAB F29 in 2018**

Variety	Plant population (000/ha)	Stem population (000/ha)	Total tuber population (000/ha)	Total tuber yield (t FW/ha)	Tuber DM concentration (%)
Cara	44.4	137	542	58.0	23.3
Estima	43.2	74	363	40.7	20.9
Infinity	44.4	98	406	41.7	23.4
Nectar	44.4	182	750	54.2	21.9
Red Fantasy	33.0	150	489	56.9	22.6
Soraya	41.3	61	321	49.9	19.0
Tyson	44.4	67	369	41.1	21.9
Mean	42.2	110	463	48.9	21.8
S.E. (24 D.F.)	1.25	14.2	22.8	2.35	0.29

#### 4.5.3. Metrics of determinacy

**Table 10** summarises the metrics of determinacy for the seven varieties. In general, there was agreement between the metrics. For example, Cara (closely followed by Red Fantasy) had the largest integrated ground cover, the smallest FW and DW harvest index and the second most main-axis above-ground nodes. Conversely, Estima, Soraya and Tyson had small values for integrated ground cover. Estima also had the largest FW and DW harvest index and together with Soraya and Infinity had the fewest main-axis leaves. As discussed in the 2017 Annual Report, the metrics based on FW and DW harvest index separated the varieties in a similar way suggesting that FW harvest index could be used if there was no access to a drying oven.

**Table 10. Metrics of determinacy in the Determinacy Experiment at NIAB in F29 2018**

Variety	Integrated ground cover (% days)	FW harvest index at H1 (%)	DW harvest index at H1 (%)	Main axis above ground nodes (No.)
Cara	8481d*	47.1a	55.2a	30.3c
Estima	3798a	71.6e	77.3d	19.5a
Infinity	4185ab	66.4d	74.9cd	17.7a
Nectar	5010c	66.7d	74.2cd	19.2a
Red Fantasy	8472d	54.7b	62.9b	29.2c
Soraya	4672bc	64.7cd	73.1c	19.3a
Tyson	4521bc	62.4c	72.4c	23.0b
Mean	5591	62.0	70.0	22.6
S.E. (24 D.F.)	231.9	0.81	1.08	0.63

\* Values suffixed with different letters are significantly different from one another at  $P < 0.05$ .

## 4.6. Library Plots in NIAB Field F29 (2018)

### 4.6.1. Emergence and ground cover

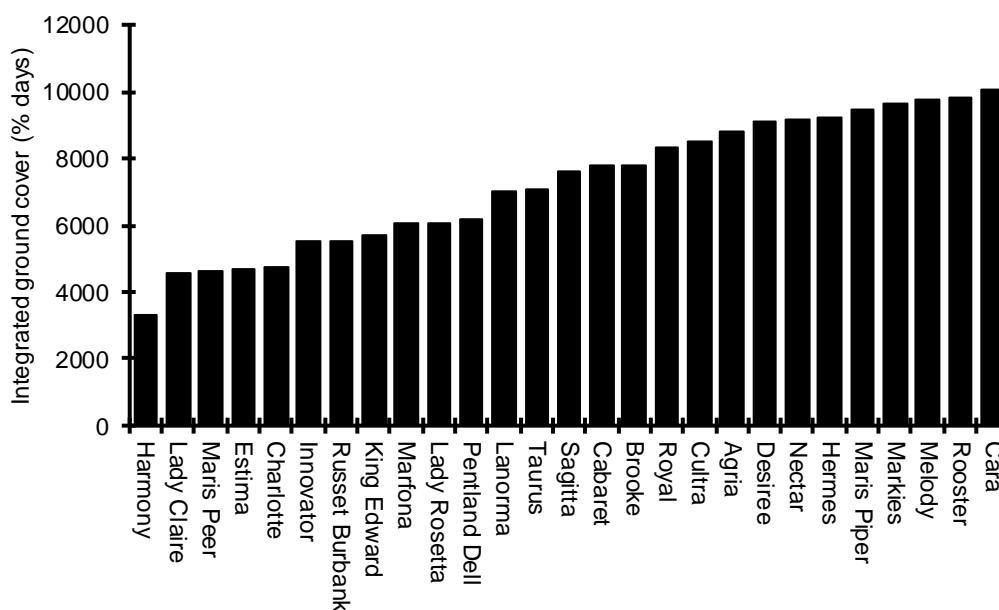
The average date of 50 % emergence was estimated as c. 14 May which was similar to the experiment in 2017 despite a late planting date. In general, there was a 7-day variation in emergence and ranged from 10 May (Brooke, Markies and Rooster) to 17 May (Estima, Cultra and Russet Burbank). The Maris Peer crop was noticeably slower than the other varieties and achieved 50 % emergence on 26 May. Therefore, in general, emergence was more synchronous in 2018 than in 2017. Most varieties achieved ground covers > 95 %, but notable exceptions to this were Harmony (where the maximum ground cover was 67 %) and Estima Charlotte, Innovator and Pentland Dell which all had maximum ground covers of c. 85%. At the final ground cover assessment (25 September), most varieties had completely senesced, however Cara had 98 % GC and Markies and Melody had GCs of 25 and 23 %, respectively. With the exception of Accord, which had a maximum GC of 67 %, all varieties attained ground covers > 90 % and the majority attained complete cover. At the final GC assessment, ground covers ranged from 100 % (Cara) to 0 % (e.g. Estima, Lady Rosetta and Marfona).

### 4.6.2. Metrics of determinacy

Due to the design of the Library Plots (small, three-row, unreplicated plots that were primarily used for demonstrating varietal difference), it was not appropriate to sample the crops mid-season to measure FW and DW harvest indices nor assess final yield.

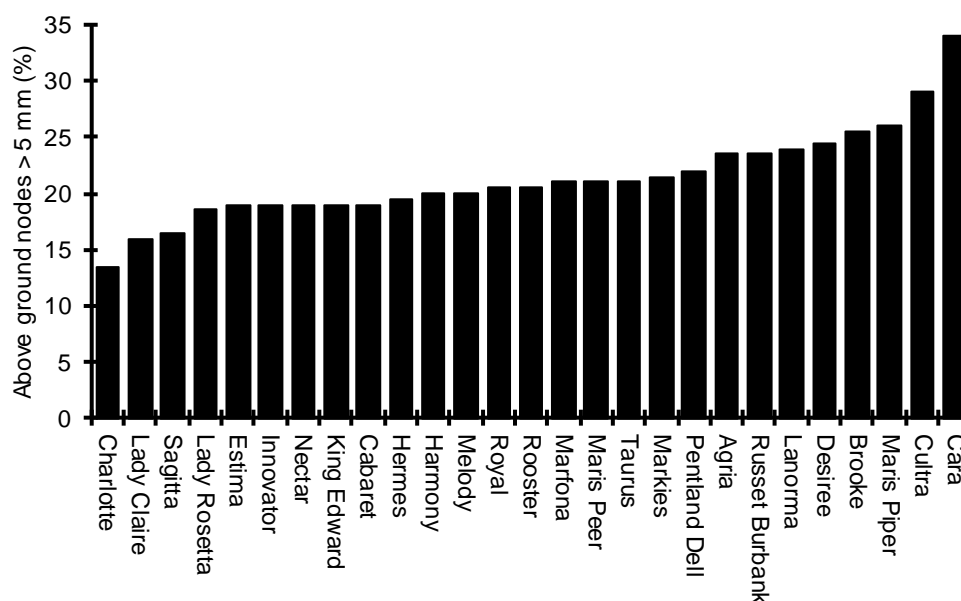
The ranking of the varieties by integrated ground cover is shown in **Figure 7**. Cara (Determinacy Group 4) had the most persistent canopy and this was underestimated since the canopy was still complete when the field had to be cleared. Persistent canopies were also produced by Maris Piper, Markies, Melody and Rooster. At the other extreme, Harmony (Determinacy Group 2) had the least extensive canopy, but this was largely due to it failing to achieve near-complete ground cover. Other varieties that had small canopies included Lady Claire, Maris Peer and Charlotte (Determinacy Group 2) and Estima (Group 1). However, King Edward and Russet Burbank (both Determinacy Group 3) were also placed toward the determinate end of the scale when using the metric of canopy persistence.

**Figure 7. Integrated ground cover for the 27 varieties in the NIAB Library Plots in F29 2018.**

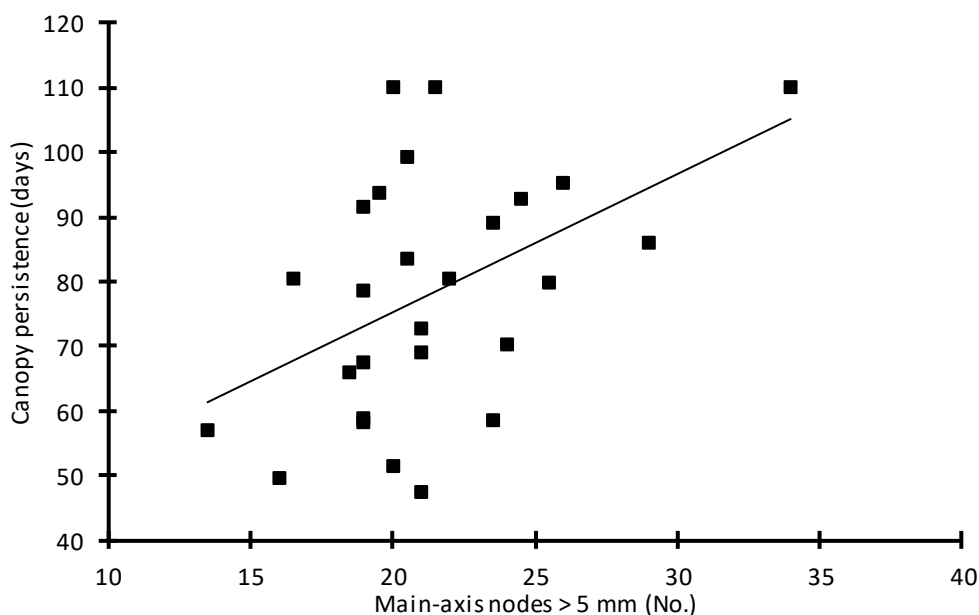


Once canopies had senesced to 50 % ground cover, main-axis node data were recorded, and node data were obtained for all 27 varieties (**Figure 8**). Cara (Group 4) had the most main-axis nodes. Other varieties with relatively high numbers of nodes included Maris Piper (Group 3) and Brooke (Group 4). At the other end of the scale, Charlotte (Group 2) produced the fewest main-axis nodes followed by Lady Claire and Lady Rosetta (Group 2) and Estima (Group 1). The relationship between canopy duration and number of main-axis nodes is shown in **Figure 9**. The relationship was statistically significant ( $P=0.013$ ), but variation in above-ground nodes explained only a small proportion (19 %) of the variation in canopy persistence. The slope of the relationship indicated that each extra node was associated with an extra 2.1 days of canopy persistence.

**Figure 8. Number of main-axis above-ground nodes in the NIAB Library Plots in 2018.**



**Figure 9. Relationship between canopy persistence and main-axis nodes in the NIAB Library Plots in F29 2018.**



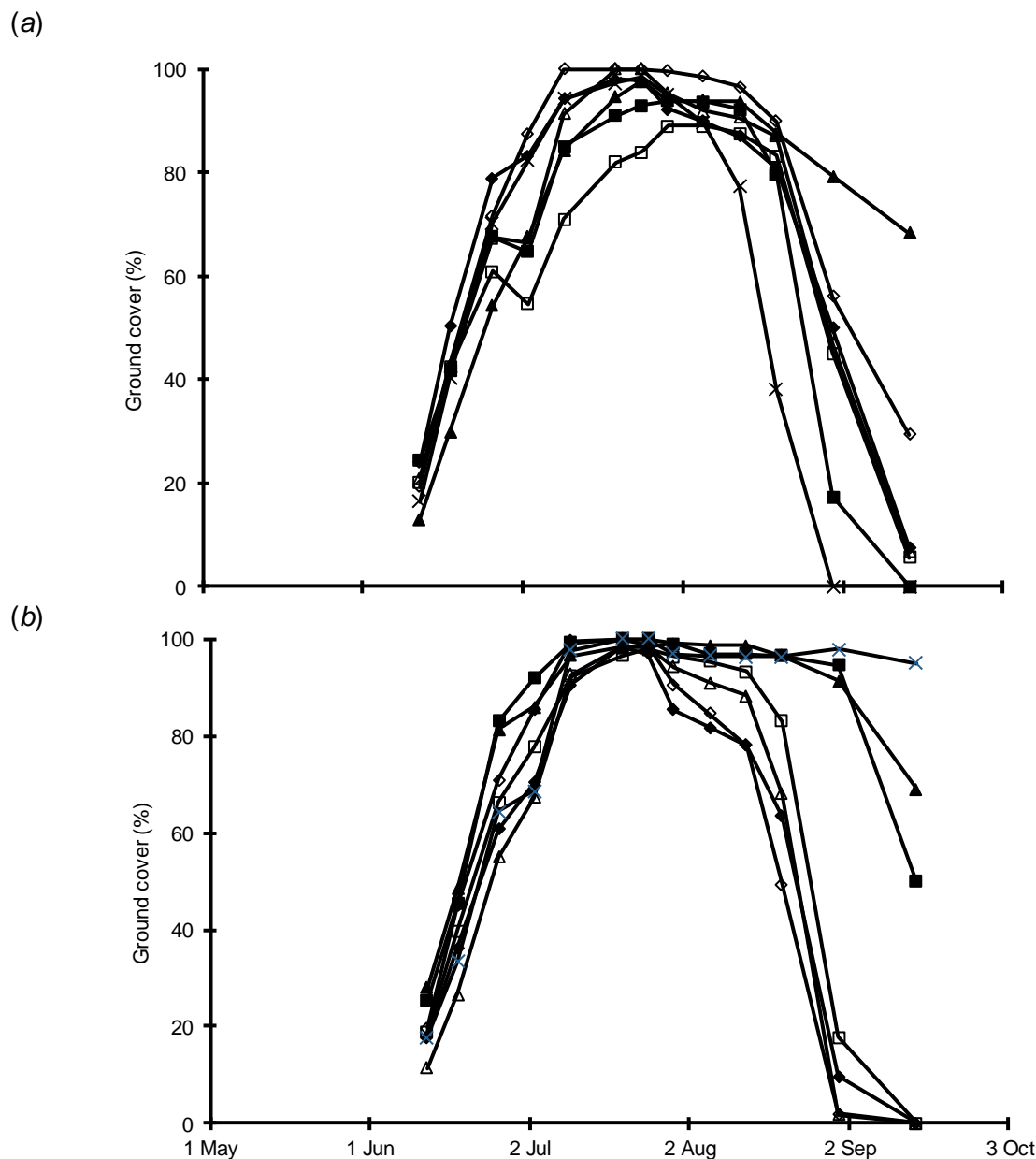
#### 4.7. Varietal Validation Experiment, Cygnet PB, Soham (2018)

##### 4.7.1. Emergence and ground cover development

At the time of writing detailed information on the time-course of plant emergence is not available. However, using established relationships between date of planting and the average date of 50 % emergence and relationships between 50 % emergence and the attainment of 50 % ground cover, the date of 50 % emergence was estimated to be 1 June and ranged from 26 May (Markies) to 3 June (Estima). Development of ground cover is shown in **Figure 10a** and **b**. The average, maximum rate of canopy expansion was 3.5 %/day (compared with 4.2 %/day in 2017). Markies, Hermes and Maris Piper had more rapid rates of canopy expansion (4.1, 4.3 and 4.7 %/day, respectively), whilst varieties such as Chicago and Atlantic were slower (1.9 and

2.6 %/day, respectively). On average, 50 % ground cover was achieved on 21 June c. 3 weeks after 50 % emergence, which was 2 days later than found in 2017. Most varieties achieved, maximum ground covers in excess of 95 %: the exceptions to this were Atlantic (94 %) and Chicago (89 %). With the exception of Bambino, all varieties achieved complete ground cover. Some varieties (e.g. Cara, Cabaret, Maris Piper and Markies) still had ground covers > 50 % when the final GC measurement was made on 15 September and for these varieties it is not possible to accurately estimate canopy persistence. The average canopy persistence (the interval between achieving 50 % ground cover in the spring and senescing to 50 % ground cover in the autumn) was 76 days, compared with 94 days in 2017. Estima, Lady Claire, Maris Peer and Vizelle all had canopy durations of < 60 days.

**Figure 10. Ground cover development in the Cygnet PB Varietal Validation Experiment. (a) Atlantic, ■; Bambino, ◆; Cabaret, ▲; Chicago, ◇; Hermes, □; Lady Rosetta, △ and Lady Claire, x. (b) Maris Piper, ■; Maris Peer, ◆; Markies, ▲; Saxon, ◇; Vizelle, □; Estima, △ and Cara, x.**



#### 4.7.2. Metrics of determinacy

Owing to the small plot size, it was not possible to take an early sample to measure varietal difference in partitioning of DM between haulm and tubers. Varietal differences in integrated ground cover and above-ground nodes are shown in **Table 11**. The integrated ground cover data should be treated with caution since, as noted above, several varieties still had substantial ground covers when the last observation was made. Regression analysis (**Figure 11**) showed that the number of above-ground nodes explained 46.4 % of the variation in canopy persistence and this relationship was statistically significant ( $P < 0.001$ ). The relationship would have been improved had the season length been longer since the canopy duration of Cara was underestimated. The slope of the relationship indicated that each extra node was associated with an increase in canopy duration 2.9 days. This value is slightly larger than that found in the NIAB Library Plots. For Markies, the number of main-axis leaves was poorly related to canopy

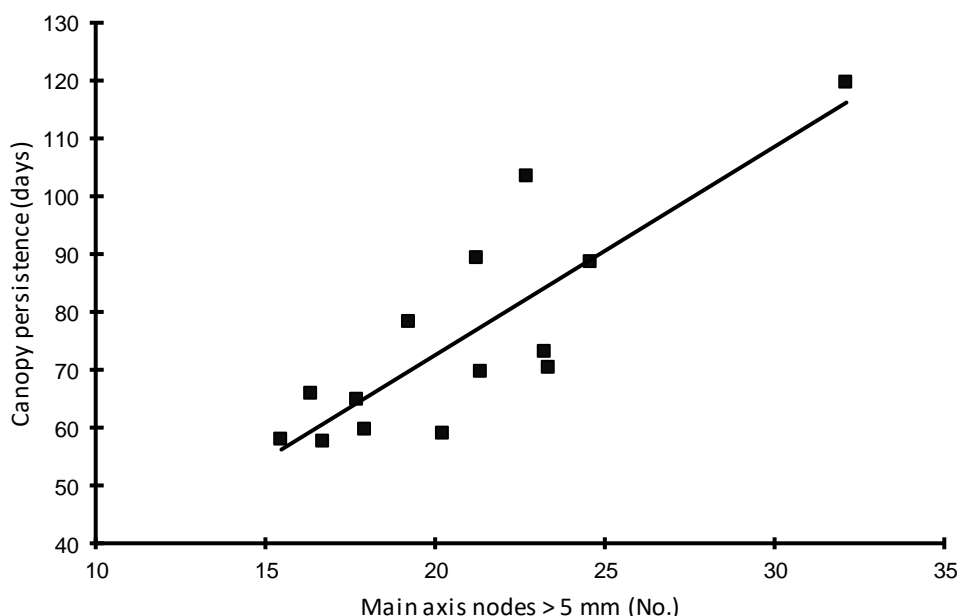
persistence. In 2017, the canopy persistence of Markies was similar (8743 %days), but there were more above-ground nodes (23.2).

**Table 11. Metrics of determinacy in the Cygnet PB Varietal Validation Experiment in 2018**

Variety	Integrated ground cover (% days)	Main-axis above-ground nodes (No.)
Atlantic	6168abc*	16.4ab
Bambino	7018de	23.2ef
Cabaret	7349e	21.2de
Cara	8300f	32.1g
Chicago	6102abc	23.3ef
Estima	5622a	16.6ab
Hermes	7461e	19.2bcd
Lady Claire	5624a	15.5a
Lady Rosetta	6786cde	21.3de
Maris Peer	5674ab	20.2cde
Maris Piper	8384f	24.6f
Markies	8474f	22.6ef
Saxon	6361bcd	17.7abc
Vizelle	5862ab	17.9abc
Mean	6799	20.6
S.E.	249.9	1.17

\* Values suffixed with different letters are significantly different from one another at P < 0.05.

**Figure 11. Relationship between canopy persistence and main-axis nodes in the Cygnet PB Varietal Validation Experiment.**



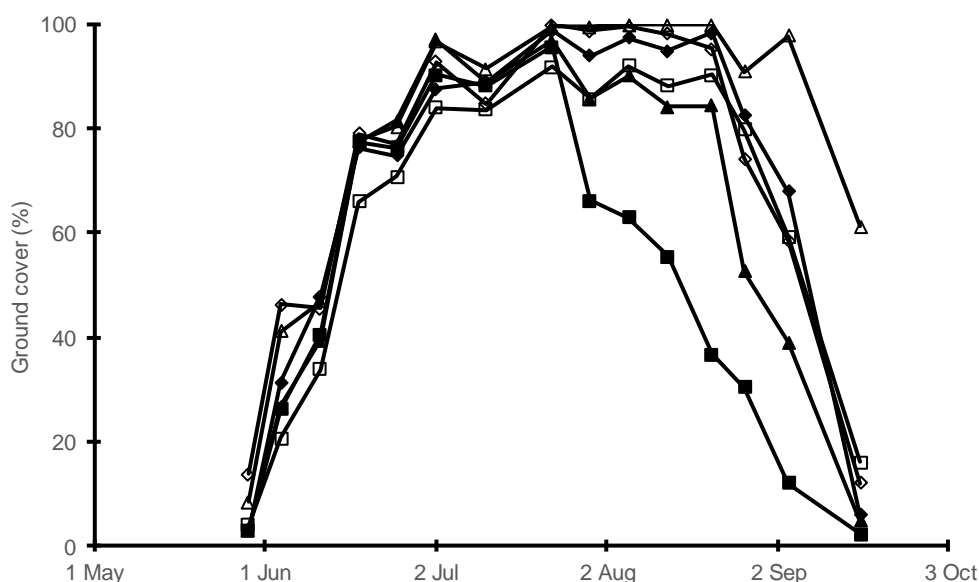
#### 4.8. Varietal Attribute Trial, Greenvale AP, Lowestoft (2018)

##### 4.8.1. Emergence and ground cover development

The mean date of achieving 50 % plant emergence was 24 May and ranged from 22 May (11.Z.114.A19) to 25 May (Jelly, Soraya and Tyson). For most varieties, final plant emergence was > 95 % of that intended. The exception was 11.Z.114.A19 where final emergence was

c. 91 % of that intended. The development of ground cover is shown in **Figure 12**. The average interval between 50 % emergence and achieving 50 % ground cover was 18 days compared with 22 days in 2017. All the varieties produced complete or near-complete canopies. The interval between 50 % GC in the expanding canopy and 50 % in the senescing canopy ranged from 65 days (Estima) to 106 days in the unnamed clone, 11.Z.114.A19.

**Figure 12. Development of ground cover in the Greenvale AP Variety Attribute Experiment. Estima, ■; Jelly, ◆; Soraya, ▲; Tyson, □; 11.Z.114.A9, ◇ and 11.Z.114.A19, △.**



#### 4.8.2. Yields at the first and second samplings

At the first sampling, mainstem populations averaged 114 000/ha and ranged from 57 000/ha (Tyson) to 192 000 in 11.Z.114.A9 (**Table 12**). Compared with 2017, when the average rate of canopy expansion was 4.3 %/day, the average rate in 2018 was slower and averaged 3.3 %/day. Tuber populations showed a two-fold variation from 264 000/ha in Tyson to 542 000/ha in 11.Z.114.A9. At 55 DAE, the mean tuber yield was 26.9 t/ha, but there was considerable variation from 22.9 t/ha in Tyson to 31.0 t/ha in Estima. The unnamed variety 11.Z.114.A9 had the greatest tuber DM concentration (23.1 %) whereas Soraya and 11.Z.114.A19 had the smallest (19.9 %).

**Table 12. Components of yield on 19 July (55 DAE) in the Greenvale AP Variety Attribute Experiment in 2018**

Variety	Plant population (000/ha)	Stem population (000/ha)	Total tuber population (000/ha)	Total tuber yield (t FW/ha)	Tuber DM concentration (%)
Estima	41.5	92	351	31.0	21.7
Jelly	41.5	109	330	29.0	20.9
Soraya	41.5	88	335	28.4	19.9
Tyson	41.5	57	264	22.9	20.3
11.Z.114.A9	32.8	192	542	23.0	23.1
11.Z.114.A19	39.8	147	492	27.3	19.9
Mean	39.8	114	386	26.9	21.0
S.E. (10 D.F.)	2.74	15.7	32.9	2.72	0.70

Numerically, stem and tuber populations were slightly larger for all varieties at the second when compared with the first harvest (**Table 13**). Between the first and second samplings, average tuber FW yield increased from 26.9 to 59.7 t/ha. Whilst there were some numeric differences in FW yield between varieties, these differences were not statistically significant (**Table 13**). Tuber DM concentrations varied from 18.3 % (Soraya) to 23.6 % (11.Z.114.A9).

**Table 13. Components of yield on 17 September (115 DAE) in the Greenvale AP Variety Attribute Experiment in 2018**

Variety	Plant population (000/ha)	Stem population (000/ha)	Total tuber population (000/ha)	Total tuber yield (t FW/ha)	Tuber DM concentration (%)
Estima	41.5	98	404	50.2	20.5
Jelly	39.8	114	335	64.9	21.0
Soraya	41.5	90	385	62.0	18.3
Tyson	41.5	57	268	54.7	21.0
11.Z.114.A9	39.8	235	670	60.2	23.6
11.Z.114.A19	41.5	159	580	66.4	22.1
Mean	40.9	126	440	59.7	21.1
S.E. (10 D.F.)	1.05	18.2	43.6	4.94	0.31

#### 4.8.3. Metrics of determinacy

**Table 14** shows candidate determinacy metrics derived from measurement of ground cover, sample data or from non-destructive counting of above-ground, main-axis nodes. There was a reasonable degree of consistency between the metrics. All four metrics placed Estima at the determinate end of the scale and the unnamed variety 11.Z.114.A19 at the indeterminate end. Soraya would be classified as similar to Estima (i.e. determinate) whilst 11.Z.114.A9 would, on most metrics, be placed at the indeterminate end of the scale, but not to the extent of 11.Z.114.A19.

**Table 14. Metrics of determinacy for the GVAP Variety Attribute Experiment in 2018**

Variety	Integrated ground cover (% days)	FW harvest index at H1 (%)	DW harvest index at H1 (%)	Main axis above ground nodes (No.)
Estima	6038a*	68d	78c	16.6ab
Jelly	8260cd	60bc	68b	20.6c
Soraya	7475b	66d	75c	16.1a
Tyson	7605bc	61c	71b	20.6c
11.Z.114.A9	8393d	54a	65a	19.6bc
11.Z.114.A19	9368e	57ab	64a	25.3d
Mean	7857	61	70	19.8
S.E. (10 DF)	222.3	1.0	1.1	0.95

\* Values suffixed with different letters are significantly different from one another at  $P < 0.05$

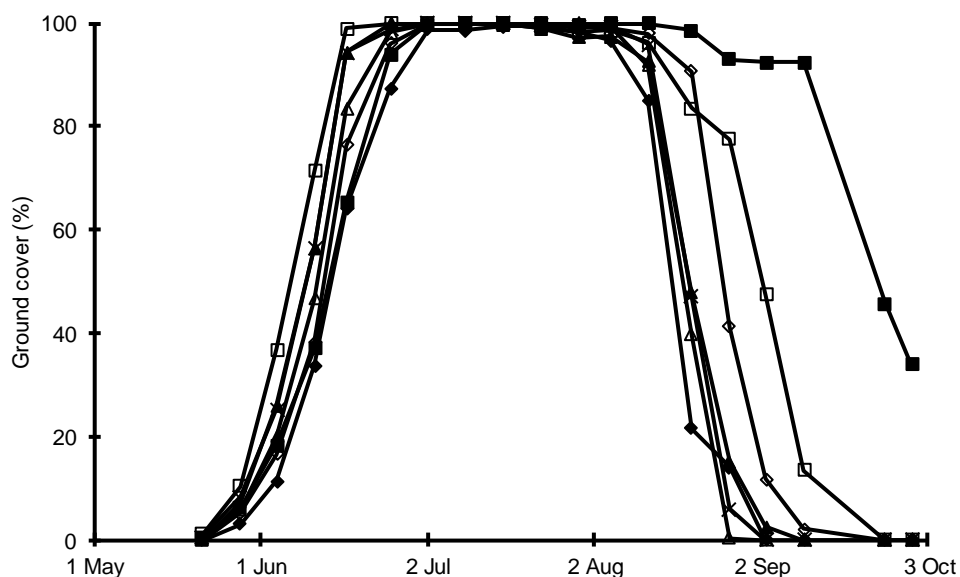
## 4.9. Determinacy Expt in NIAB Field 30 (2019)

### 4.9.1. Emergence and ground cover development

The date of 50 % emergence for all seven varieties differed by only one day and average 20 May (34 days after planting, DAP). This was similar to 2018 (30 DAP) but shorter than that observed in 2017 (45 DAP). The pattern of ground cover development is shown in **Figure 13**. As the canopies expanded, Molly achieved 50 % ground cover at 19 DAE compared with

26 DAE for Estima and 25 DAE for Cara. The rapid expansion of the Molly canopy was likely to be a consequence of its large stem population (**Table 15**). The most persistent canopy was Cara (107 days from 50 % ground cover as the canopy expanded in the spring to 50 % ground cover as it senesced in the autumn). The least persistent canopies were those of Soraya and Estima (69 and 65 days, respectively). Compared with a similar experiment in 2018, crop canopies were much more persistent. For example, in 2018 the canopies of Cara and Estima had persistences of 89 and 41 days, respectively. This difference was probably due to a combination of improved soil conditions and a more benign season in 2019.

**Figure 13. Development of ground cover in Determinacy Experiment NIAB CUF. Cara, ■; Estima, ◆; A13, ▲; Molly, □; Nectar, ◇; Soraya, △ and Tyson, x.**



#### 4.9.2. Yield at the first and second samplings

Compared with 2018, plant establishment in 2019 was much better and, at the first sampling, most treatment achieved the intended plant population (**Table 15**). At the first crop sampling, stem populations ranged from 74 000/ha in Tyson to 337 000/ha in Molly. Estima had the smallest tuber population (415 000) and Molly the largest (692 000/ha). Total tuber FW yields averaged 21.8 t/ha (30.9 t/ha in 2018) and ranged from 11.8 t/ha (Cara) to 25.7 t/ha (Soraya). Tuber DM concentrations ranged from 14.8 % (Cara) to 17.1 % (Estima) with an average of 16.1 %. For comparison, at the first sampling in 2018, tuber dry matter concentrations for Estima and Cara were 19.0 and 20.6 %, respectively. At the second sampling, stem populations were broadly similar to those found at the initial sampling and had a mean value of 139 000/ha (**Table 16**) and the mean, total tuber population was 477 000/ha. Between the two harvests, mean total FW yields increased from 21.8 to 63.8 t/ha. The smallest total FW yield was produced by Estima (47.9 t/ha) and the largest yields were produced by Molly, Nectar and Soraya (75.6, 73.0 and 71.9 t/ha, respectively). Soraya had the smallest tuber dry matter concentration (17.2 %) and A13 the greatest (22.7 %).

**Table 15. Components of yield on 8 July (49 DAE) in the Determinacy Experiment at NIAB F30 in 2019**

Variety	Plant population (000/ha)	Stem population (000/ha)	Total tuber population (000/ha)	Total tuber yield (t FW/ha)	Tuber DM concentration (%)
Cara	44.4	141	467	11.8	14.8
Estima	44.4	83	415	22.8	17.1
A13	44.4	175	524	21.0	16.6
Molly	44.4	337	692	24.8	16.9
Nectar	44.4	119	519	22.9	16.3
Soraya	44.4	112	515	25.7	15.1
Tyson	43.8	74	462	23.8	16.0
Mean	44.3	149	514	21.8	16.1
S.E. (24 D.F.)	0.23	7.2	23.8	0.88	0.22

**Table 16. Components of yield on 8 October (141 DAE) in the Determinacy Experiment at NIAB F30 in 2019**

Variety	Plant population (000/ha)	Stem population (000/ha)	Total tuber population (000/ha)	Total tuber yield (t FW/ha)	Tuber DM concentration (%)
Cara	44.4	134	418	58.9	20.7
Estima	43.8	75	341	47.9	20.5
A13	43.8	163	543	60.7	22.7
Molly	44.4	293	674	75.6	22.0
Nectar	41.9	118	446	73.0	19.7
Soraya	44.4	119	492	71.9	17.2
Tyson	43.8	71	423	58.8	20.9
Mean	43.8	139	477	63.8	20.5
S.E. (24 D.F.)	1.07	19.7	22.6	3.59	0.23

#### 4.9.3. Metrics of determinacy

**Table 17** summarises the metrics of determinacy for the seven varieties. In general, there was agreement between the metrics. For example, Cara had the largest integrated ground cover, the smallest FW and DW harvest index and the most main-axis above-ground nodes. Conversely, Estima had the smallest values for integrated ground cover, the largest harvest index and the fewest above-ground nodes. The variety Molly seemed to be more like Cara (although not as indeterminate), whilst Soraya behaved as a determinate variety and was more like Estima. The metrics for A13 showed some inconsistency: the number of nodes and integrated ground cover suggest it was similar to Estima, but the harvest index data suggested that it may more indeterminate.

**Table 17. Metrics of determinacy in the Determinacy Experiment at NIAB F30 in 2019**

Variety	Integrated ground cover (% days)	FW harvest index at H1 (%)	DW harvest index at H1 (%)	Main axis above ground nodes (No.)
Cara	10270e	23.4a	29.8a	33.8e
Estima	6408a	56.2e	65.0d	19.5a
A13	7272bc	36.2b	45.7b	21.3b
Molly	8698d	36.6b	48.0b	26.8d
Nectar	7561c	48.6d	56.6c	23.2c
Soraya	6924ab	48.1d	56.6c	19.3a

Tyson	7238bc	44.8c	55.8c	20.6ab
Mean	7767	42.0	51.0	23.5
S.E. (24 D.F.)	198.0	1.12	1.09	0.55

\* Values with different letters are significantly different from one another at  $P < 0.05$ .

## 4.10. Library Plots in NIAB Field 30 (2019)

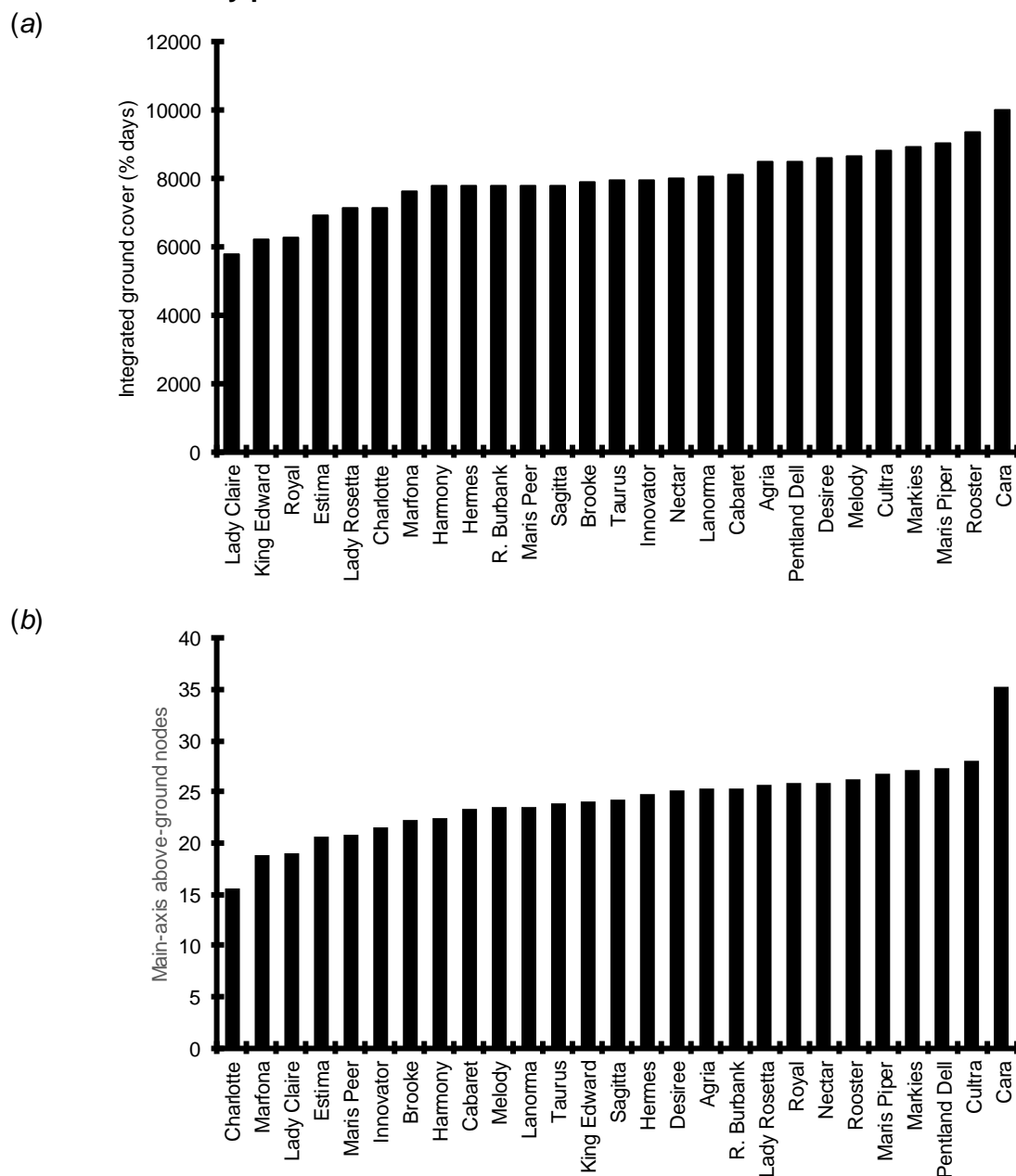
### 4.10.1. Emergence and ground cover

The average date of 50 % emergence was estimated as c. 12 May which was similar to that found in 2018 (14 May) and 2017 (15 May). This was a 9-day variation in emergence and ranged from 8 May (Desiree, Nectar and Rooster) to 1 May (Lady Claire). All varieties achieved complete (100 %) ground cover. At the final ground cover assessment (20 September), most varieties had completely senesced or had ground covers < 10%, however Cara had 49 % GC.

### 4.10.2. Metrics of determinacy

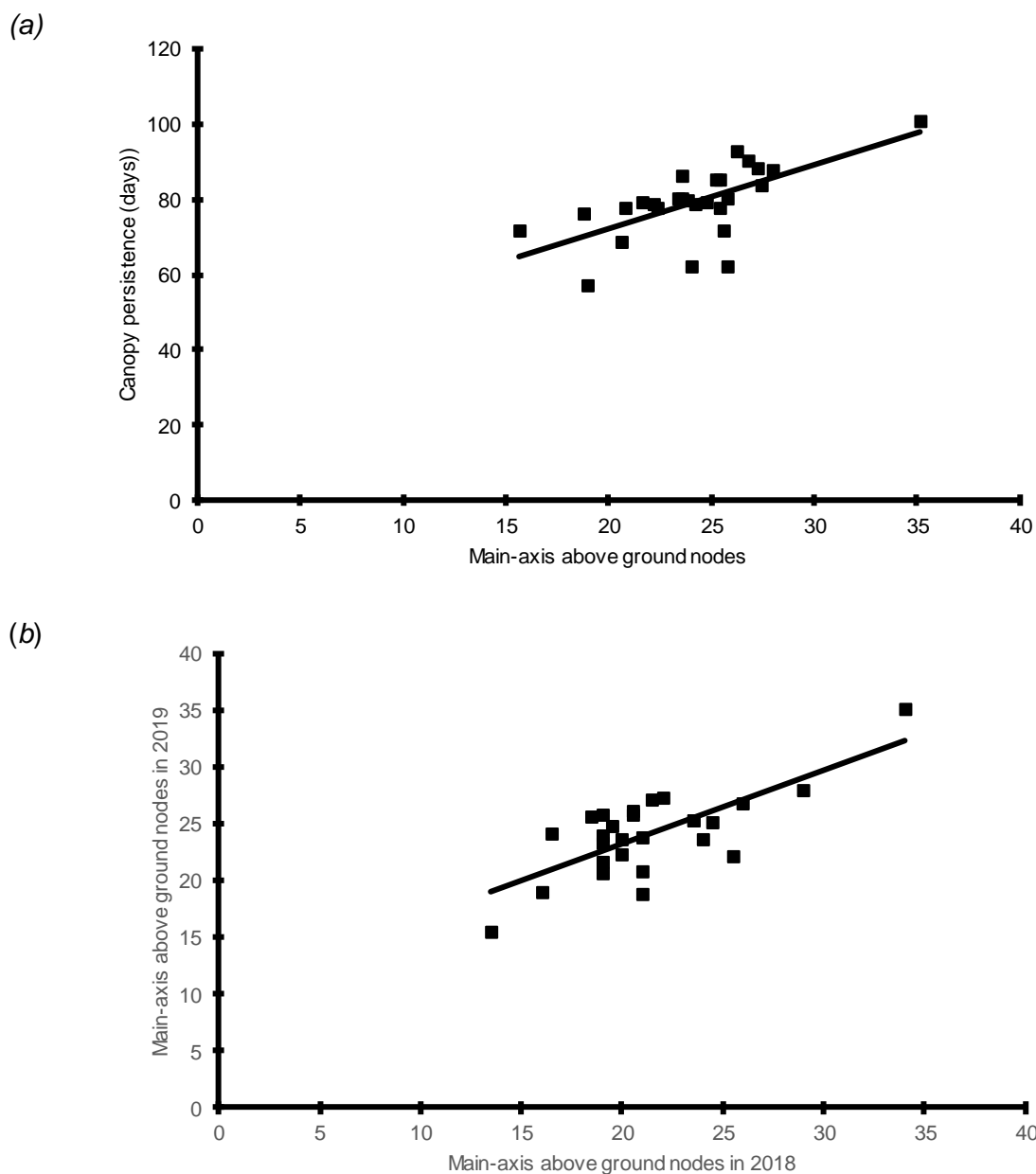
Due to the design of the Library Plots (small, three-row, unreplicated plots) that were primarily used for demonstrating varietal difference in training courses) it was not appropriate to sample the crops mid-season to measure FW and DW harvest index nor assess final yield. The ranking of the varieties by integrated ground cover is shown in **Figure 14a**. Cara (Determinacy Group 4) had the most persistent canopy and this was slightly underestimated since the canopy was still c. 50 % at the time of final assessment. Persistent canopies were also produced by Maris Piper, Markies, Melody, Rooster and Cultra. At the other extreme, Lady Claire (Determinacy Group 2) had the least extensive canopy. Other varieties that had small canopies included Estima (Determinacy Group 1) and Lady Rosetta, (Determinacy Group 2). However, there were some anomalies: King Edward (Determinacy Group 3) and Royal (Determinacy Group 4) were also placed toward the determinate end of the scale when using the metric of canopy persistence. In part, this discrepancy may be due to lodging of the large canopies which would have resulted in underestimates of ground cover.

**Figure 14. (a) Integrated ground cover and (b) above-ground nodes for the 27 varieties in the NIAB Library plots in F30 in 2019**



Once canopies had senesced to c. 50 % ground cover, main-axis node data were recorded, and node data were obtained for all 27 varieties (**Figure 14b**). Cara (Group 4) had the most main-axis nodes. Other varieties with relatively high numbers of nodes included Maris Piper and Cultra (Group 3) and Markies (Group 4). At the end of the scale, Charlotte (Group 2) produced the fewest main-axis nodes together with Marfona, Lady Claire and Lady Rosetta (Group 2) and Estima (Group 1). Again, there are some anomalies, for example: Brooke (Group 4) is situated at the determinate end of the scale and produce a similar number of nodes to Innovator (Group 1). The relationship between canopy duration and number of main-axis nodes is shown in **Figure 15a**. The relationship was statistically significant ( $P < 0.001$ ) and variation in above ground nodes explained only c. 40 % of the variation in canopy persistence. The slope of the relationship indicated that each extra node was associated with an extra 1.7 days of canopy persistence (compared with 2.1 in 2018).

**Figure 15. (a) Relationship between canopy persistence and main-axis nodes in the NIAB Library Plots in 2019 and (b) relationship between main axis nodes recorded in 2018 and 2019.**



**Figure 15b** compares values main-axis above-ground nodes for varieties grown in 2018 and 2019. As found in previous work (Allison *et al.* 2000), there was, in general, a good correlation in the number of above ground-nodes measured across seasons.

#### **4.11. Varietal Attribute Trial, Greenvale AP, Icklingham (2019)**

##### **4.11.1. Emergence and ground cover development**

The contrasting N treatment had little effect on crop emergence: the mean date of achieving 50 % plant emergence was 18 and 19 May in the low and high N treatments, respectively. In the low N treatments, the date of 50 % emergence ranged from 16 May (11.Z.114.A9) to 21 May (Estima and Jelly). In the high N treatments, the range was from 15 May (11.Z.114.A9) to 20 May (Estima, Jelly and Tyson). Near-complete emergence was achieved in all varieties,

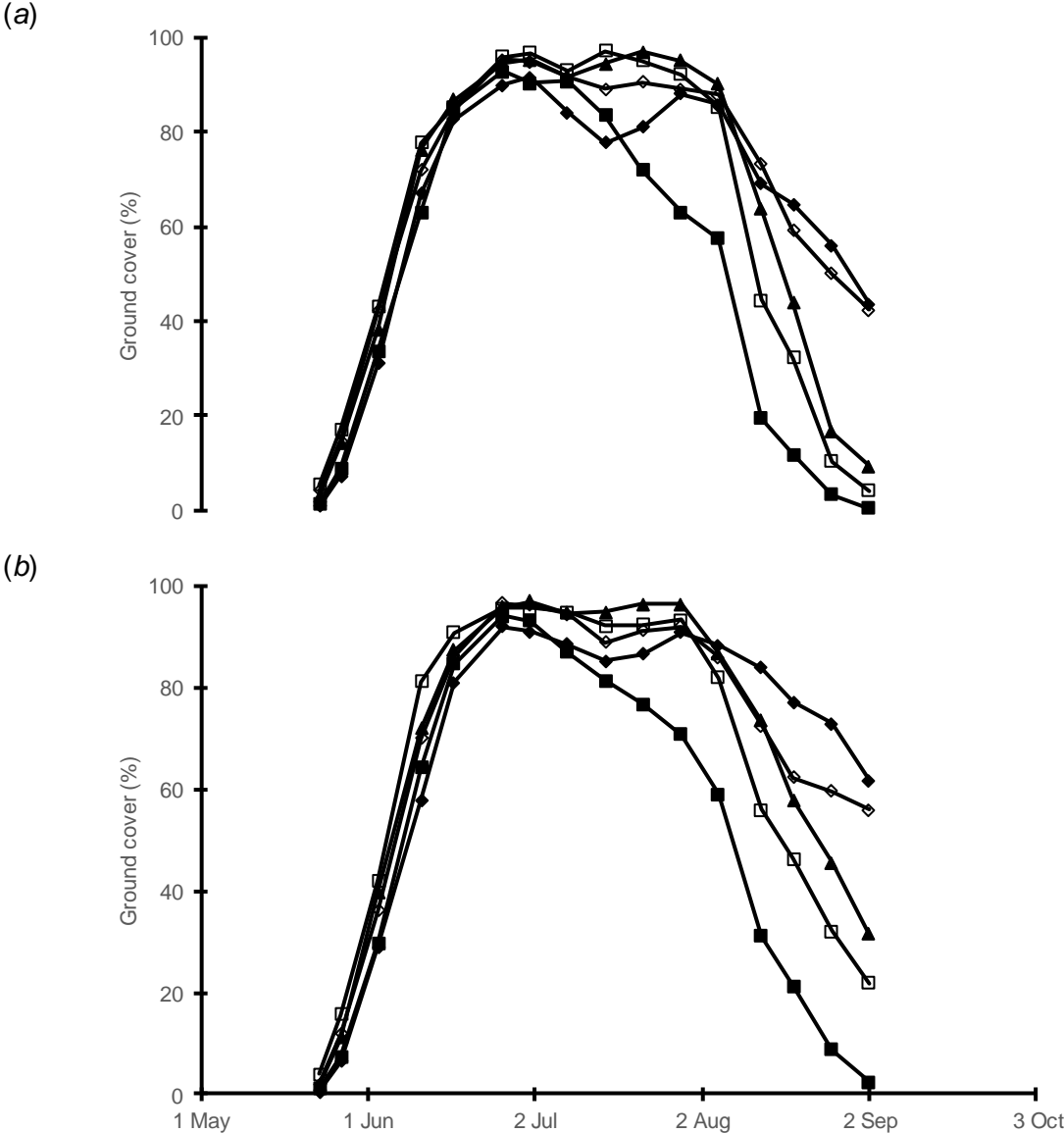
irrespective of N application. The development of ground cover is shown in **Figure 16a** (Low N) and **Figure 16b** (High N). The average interval between 50 % emergence and achieving 50 % ground cover was 19 days for the Low N treatments and 18 days for the High N. Irrespective of N application, Tyson had the shortest interval from 50 % emergence to 50 % ground cover (16.6 days) and 11.Z.114.89 the longest (29.8 days). All the varieties produced complete or near-complete canopies. The interval between 50 % GC in the expanding canopy and 50 % in the senescing canopy ranged from 59 days (Estima, Low N) to 102 days (Jelly, High N).

#### **4.11.2. Yields at the first and second samplings**

At the first sampling (8 July), achieved plant population were 100 % of that intended for all varieties and N comparisons. On average, stem populations were similar for both the Low and High N treatment and, for both N treatments were larger in 11.Z.114.A9 and 11.Z.114.A19 than in Estima, Jelly or Tyson (

**Table 18**). Tuber population averaged 541 000 and 474 000/ha in the Low and High N experiments, respectively. In both experiments, Estima and Jelly had smaller total tuber populations than Tyson, 11.Z.114.A9 and 11.Z.114.A19. In the Low N experiment, total tuber yields ranged from 21.2 t/ha (Jelly) to 34.4 t/ha (Tyson) with mean of 27.1 t/ha. In the High N experiment, total tuber yield varied from 17.0 t/ha (Jelly) to 30.4 t/ha (Tyson) with a mean yield of 23.5 t/ha. It is likely that the difference yields between the two experiments was a consequence of poor dry matter partitioning. There was little effect of N on the average tuber DM concentration and in both experiments 11.Z.114.A9 had the largest tuber DM concentration and 11.Z.114.A19 the smallest.

**Figure 16. Development of ground cover in the Greenvale AP Variety Attribute Experiment (a), Low N and (b) High N. Estima, ■; Jelly, ◆; Tyson, ▲; 11.Z.114.A9, □ and 11.Z.114.A19, ◇.**



**Table 18. Components of yield on 8 July (51 DAE) for two contrasting N regimes in GvAP Variety Attribute Experiment in 2019**

Variety	Plant population (000/ha)	Stem population (0000/ha)	Total tuber population (1000/ha)	Total tuber yield (t FW/ha)	Tuber DM concentration (%)
<b>Low N</b>					
Estima	42.1	126	432	28.2	17.8
Jelly	42.1	109	421	21.2	17.6
Tyson	42.1	122	627	34.4	17.2
11.Z.114.A9	42.1	170	564	27.5	18.5
11.Z.114.A19	42.1	159	662	24.1	16.6
Mean	42.1	137	541	27.1	17.5
S.E. (12 D.F.)	-	8.3	38.7	1.28	0.14
<b>High N</b>					
Estima	42.1	118	381	26.1	17.9
Jelly	42.1	113	350	17.0	17.3
Tyson	42.1	116	534	30.4	16.9
11.Z.114.A9	42.1	202	580	23.3	18.7
11.Z.114.A19	42.1	147	526	20.9	16.4
Mean	42.1	139	474	23.5	17.4
S.E. (12 D.F.)	-	7.3	32.6	1.54	0.18

Numerically, at the second sampling on 4 September stem and tuber population were similar to those recorded at the first sampling (**Table 19**). Between the first and second sampling, the average total tuber FW yield increased from 27.1 to 59.0 t/ha in the Low N experiment and from 23.5 to 56.9 t/ha in the High N experiment. In both N regimes, Tyson produced the largest yield, whereas Estima or 11.Z.114.A9 had the smallest in the High or Low N experiments, respectively. Between the two samplings, tuber dry matter concentration had increased by c. 2 percentage points and, as found at the first sampling, N application rate had little effect on tuber DM concentration. In both experiments, 11.Z.114.A9 had the greatest dry matter concentration, whereas Jelly had the smallest.

**Table 19. Components of yield on 4 September (109 DAE) in the GVAP Variety Attribute Experiment 2019**

Variety	Plant population (000/ha)	Stem population (000/ha)	Total tuber population (000/ha)	Total tuber yield (t FW/ha)	Tuber DM concentration (%)
<b>Low N</b>					
Estima	40.8	114	450	55.0	21.2
Jelly	42.1	104	350	56.2	20.8
Tyson	40.8	118	655	74.0	21.5
11.Z.114.A9	42.1	164	568	57.5	23.2
11.Z.114.A19	42.1	155	592	52.2	22.8
Mean	41.6	131	523	59.0	21.9
S.E. (12 D.F.)	0.87	5.5	39.0	4.26	0.31
<b>High N</b>					
Estima	42.1	121	421	46.3	20.7
Jelly	40.8	97	397	61.7	20.3
Tyson	40.8	97	645	73.0	20.7
11.Z.114.A9	42.1	160	651	54.8	22.8
11.Z.114.A19	42.1	150	556	48.5	21.7
Mean	41.6	125	534	56.9	21.3
S.E. (12 D.F.)	0.87	12.4	42.3	3.99	0.35

#### 4.11.3. Metrics of determinacy

**Table 20** shows candidate determinacy metrics derived from measurement of ground cover, sample data or from non-destructive counting of above-ground, main-axis nodes. There was a reasonable degree of consistency between the metrics. All four metrics placed Estima at the determinate end of the scale and the unnamed variety 11.Z.114.A19 at the indeterminate end. Jelly would be classified as indeterminate whilst 11.Z.114.A9 would, on most metrics, be placed at the indeterminate end of the scale but not to the extent of 11.Z.114.A19.

**Table 20. Metrics of determinacy for the GVAP Variety Attribute Experiment in 2019**

Variety	Integrated ground cover (% days)	FW harvest index at H1 (%)	DW harvest index at H1 (%)	Main axis above ground nodes (No.)
<b>Low N</b>				
Estima	5421a	58.6c	69.0d	14.5a
Jelly	7730cd	52.2b	60.7b	15.3a
Tyson	7059bc	51.6b	64.3c	15.4a
11.Z.114.A9	6810b	49.4b	59.5b	15.4a
11.Z.114.A19	8073d	45.7a	51.7a	21.4b
Mean	7018	51.5	61.0	16.4
S.E. (12 DF)	262.4	1.07	0.93	0.55
<b>High N</b>				
Estima	5694a	57.2c	68.5d	13.7a
Jelly	8654d	48.9b	57.6b	18.8b
Tyson	7780bc	48.8b	61.6c	18.5b
11.Z.114.A9	7359b	46.1ab	57.8bc	15.1a
11.Z.114.A19	8494cd	44.1a	49.3a	23.5c
Mean	7596	49.0	59.1	17.9
S.E. (12 DF)	239.6	1.47	1.28	0.68

\* Values with different letters are significantly different from one another at  $P < 0.05$

#### 4.12. Allocation to nitrogen groups

Using the methods described in Section 3.12 candidate metrics measured at NIAB, Greenvale AP and Cygnet PB were converted into the nitrogen groupings used by the Nutrient Management Guide (RB209), and the results are shown in **Table 21** to **Table 23** respectively. At NIAB (**Table 21**), when the errors are considered, there was broadly similar values for the metrics for the test varieties common to the three seasons (Nectar, Soraya and Tyson). Discrepancies between seasons may be due to differential varietal sensitivity to contrasting soil and environmental conditions particularly in 2017 and 2018. In the experiments hosted by Greenvale AP, the four methods gave reasonably similar rankings which seemed sensible (**Table 22**). Collectively, the ranking suggested that two unnamed clones would have similar N requirement to Jelly with 11.Z.114 A19 possibly being even more indeterminate and requiring less N than Jelly to achieve a similar canopy persistence. The experiments at Cygnet in 2017 (**Table 23**) tested 14 varieties and used Lady Claire (Determinacy Group 2) and Markies (4) as references. In 2017, the experiment at Cygnet was compromised due to a high N application rate which resulted in many varieties at complete ground cover when the experiment ceased in the autumn. In 2018, the N application rate was reduced and the control varieties Estima (1) and Cara (4) were at the extreme ends of the determinacy groups and this permitted better separation of varieties (**Table 23**). Using integrated ground cover or above ground nodes to allocate into N groups seemed to give broadly consistent and sensible results (e.g. Lady Claire Group 1; Lady Rosetta Group 2 and Saxon Group 2). However, for some varieties (e.g. Markies) there was a large disparity between the group determined by integrated ground cover and that determined by counting above ground nodes. It is possible that, in this case, the number of above ground nodes was underestimated. The grouping data suggested that the underlying metrics are sensitive to how the experiments were managed e.g. nitrogen application rates. It is also likely that non-synchronous emergence may also have an effect on metrics involving harvest index (see Review of Harvest Index Methodology, page 51). Intuitively, it seems likely that groupings based on an average of more than one metric may be more reliable and this will be further investigated in 2019. The mean nitrogen grouping determined by each method and the overall mean nitrogen grouping for all 26 varieties are shown in **Table 24**. For comparison, the determinacy groups have been calculated to 1 decimal place but in practice these would be rounded to integer values. Within the limits of error, there was good agreement between the published nitrogen groupings in the Nutrient Management Guide (RB209) and those calculated using the individual metrics. For example, Atlantic and Saxon (both Nitrogen Group 2 in RB209) had average metrics of 2.0 and 2.1, respectively. Lady Claire and Lady Rosetta are both Nitrogen Group 2 in RB209 and the average metric from the experiments was 1.5 and 2.8. This is of significance, since many growers and agronomist would consider Lady Claire to have a larger N requirement than Lady Rosetta when grown under similar conditions.

**Table 21. Derived determinacy grouping for the Determinacy Experiment at NIAB 2017-2019. The varieties in italics are the reference varieties for each experiment**

Variety	Determinacy ranking based on				
	Integrated ground cover	FW harvest index at H1	DW harvest index at H1	Main axis above ground nodes	Mean of all metrics
<b>2017</b>					
<i>Cara</i>	4.0d	4.0d	4.0d	4.0d	4.0e
<i>Estima</i>	1.0a	1.0a	1.0a	1.0a	1.0a
Infinity	2.8c	2.1b	1.9b	1.5ab	2.0c
Nectar	2.6c	3.0c	3.0c	2.5c	2.8d
Soraya	1.0a	1.1a	1.1a	1.1a	1.1a
Tyson	1.3a	1.9b	1.8b	1.8b	1.7b
0751	1.9b	2.1b	2.1b	1.7b	1.9c
Mean	2.1	2.2	2.1	1.9	2.1
S.E. (24 D.F.)	0.17	0.08	0.13	0.18	0.07
<b>2018</b>					
<i>Cara</i>	4.0d	4.0e	4.0d	4.0d	4.0f
<i>Estima</i>	1.0a	1.0a	1.0a	1.0a	1.0a
Infinity	1.3ab	1.6b	1.4b	1.0a	1.4b
Nectar	1.8c	1.6b	1.4b	1.2a	1.5c
Red Fantasy	3.8d	3.1d	2.9c	3.7c	3.4e
Soraya	1.6bc	1.9b	1.6b	1.2a	1.5c
Tyson	1.5bc	2.1c	1.6b	2.0b	1.8d
Mean	2.1	2.2	2.0	2.0	2.1
S.E. (24 D.F.)	0.12	0.09	0.11	0.07	0.05
<b>2019</b>					
<i>Cara</i>	4.0e	4.0e	4.0d	4.0a	4.0f
<i>Estima</i>	1.0a	1.0a	1.0a	1.0f	1.0a
Molly	2.8d	2.8d	2.4c	2.5e	2.7e
Nectar	1.9c	1.7b	1.7b	1.8d	1.8c
Soraya	1.4ab	1.8bc	1.7b	1.1ab	1.5b
Tyson	1.6bc	2.0c	1.8b	1.3bc	1.7c
A13	1.7bc	2.8d	2.7c	1.4c	2.2d
Mean	2.1	2.3	2.2	1.9	2.1
S.E. (24 DF)	0.14	0.10	0.09	0.08	0.06

\* values with different letters are significantly different from one another at P < 0.05

**Table 22. Derived determinacy groups for the GVAP Variety Attribute Experiment 2017-2019. The varieties in italics are the reference varieties for the experiment**

Variety	Determinacy ranking based on				
	Integrated ground cover	FW harvest index at H1	DW harvest index at H1	Main axis above ground nodes	Mean of all metrics
<b>2017</b>					
<i>Estima</i>	1.0a	1.0a	1.0a	1.0a	1.0a
<i>Red Fantasy</i>	3.0a	3.0d	3.0d	3.0a	3.0c
Soraya	1.6a	1.6b	1.6b	2.6a	1.8ab
Tyson	2.4a	2.2c	2.1c	2.8a	2.4bc
0751	2.5a	1.4b	1.6b	3.0a	2.1bc
Mean	2.1	1.8	1.9	2.5	2.1
S.E. (8 D.F.)	0.60	0.07	0.09	0.66	0.31
<b>2018</b>					
<i>Estima</i>	1.0a	1.0a	1.0a	1.0a	1.0a
<i>Jelly</i>	3.0c	3.0b	3.0c	3.0bc	3.0cd
Soraya	2.3b	1.5a	1.7b	1.1a	1.6b
Tyson	2.4b	2.9b	2.6c	3.0bc	2.7c
11.Z.114.A9	3.3c	3.8c	3.6d	2.1b	3.2d
11.Z.114.A19	3.9d	3.5bc	3.6d	4.0c	3.7e
Mean	2.6	2.6	2.6	2.4	2.5
S.E. (10 D.F.)	0.18	0.23	0.17	0.33	0.13
<b>2019-Low N</b>					
<i>Estima</i>	1.0a	1.0a	1.0a	1.0a	1.0a
<i>Jelly</i>	3.0cd	3.0b	3.0c	3.0a	3.0bc
Tyson	2.5bc	3.3bc	2.1b	2.9a	2.7b
11.Z.114.A9	2.3b	3.6cd	3.4d	2.4a	3.0b
11.Z.114.A19	3.3d	4.0d	4.0e	2.5a	3.4c
Mean	2.4	3.0	2.7	2.4a	2.6
S.E. (12 D.F.)	0.20	0.19	0.13	0.47	0.15
<b>2019-High N</b>					
<i>Estima</i>	1.0a	1.0a	1.0a	1.0a	1.0a
<i>Jelly</i>	3.0c	3.0b	3.0b	3.0c	3.0c
Tyson	2.4b	2.9b	2.5b	3.1c	2.8bc
11.Z.114.A9	2.1b	3.4b	3.1bc	1.7b	2.6b
11.Z.114.A19	3.0c	3.6b	3.8c	4.0d	3.6d
Mean	2.3	2.8	2.7	2.6	2.6
S.E. (12 D.F.)	0.17	0.25	0.25	0.19	0.14

\* values with different letters are significantly different from one another at P < 0.05

**Table 23. Derived determinacy groups for the Cygnet PB Varietal Validation Experiments 2017-2018. The varieties in italics are reference varieties for the experiment**

Variety	Determinacy ranking based on		
	Integrated ground cover	Main axis above ground nodes	Mean of all metrics
<b>2017</b>			
<i>Lady Claire</i>	2.0b	2.0a	2.0ab
<i>Markies</i>	4.0c	4.0e	4.0f
Agria	3.2c	3.7de	3.5ef
Atlantic	3.4c	1.9a	2.6bc
Bambino	1.3ab	3.2bcde	2.3abc
Cabaret	1.7ab	3.0bcd	2.4abc
Chicago	1.5ab	4.0e	3.7cd
Hermes	3.7c	3.5cde	3.6eef
Lady Rosetta	3.3c	3.9de	3.5ef
Maris Peer	3.3c	3.3cde	3.3de
Maris Piper	3.7c	3.9de	3.8ef
Saxon	3.1c	2.4ab	2.7cd
Vizelle	1.0a	2.8abc	1.9a
Mean	2.7	3.2	3.0
S.E. (24 D.F.)	0.31	0.32	0.23
<b>2018</b>			
<i>Cara</i>	4.0f	4.0e	4.0g
<i>Estima</i>	1.0a	1.0a	1.0a
Atlantic	1.6abc	1.1a	1.3ab
Bambino	2.6de	2.3cd	2.4de
Cabaret	2.9e	1.9bc	2.4e
Chicago	1.5abc	2.3cd	1.9cd
Hermes	3.0e	1.5ab	2.3de
Lady Claire	1.0ab	1.0a	1.0a
Lady Rosetta	2.3cde	1.9bc	2.1de
Maris Peer	1.3ab	1.8bc	1.5bc
Maris Piper	4.0f	2.6d	3.2f
Markies	3.9f	2.2cd	3.0f
Saxon	1.8bcd	1.2a	1.5abc
Vizelle	1.3ab	1.2a	1.3ab
Mean	2.3	1.9	2.1
S.E. (26 D.F.)	0.27	0.19	0.18

\* values with different letters are significantly different from one another at P < 0.05

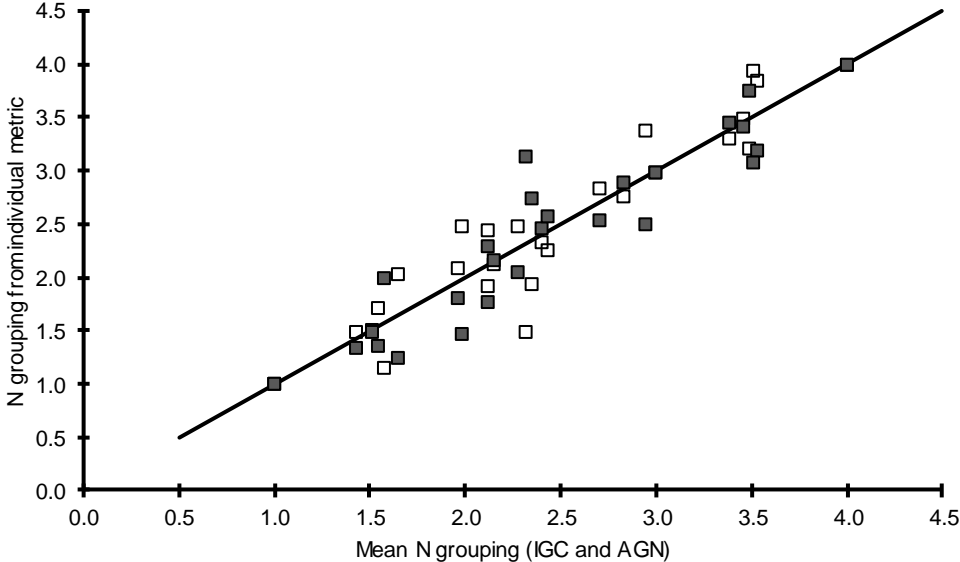
**Table 24. Summary of nitrogen groups determined using up to four methods and overall mean value. n is the number of individual observations comprising the mean value. Varieties in bold were used as controls in experiments. The varieties in italics were used as controls in some experiment but test varieties in others**

Variety (N Group in RB209)	Integrated GC		FW harvest index		DW harvest index		Above ground nodes		Mean of metrics	
	n	Mean ± S.E.	n	Mean ± S.E.	n	Mean ± S.E.	n	Mean ± S.E.	n	Mean ± S.E.
0751	8	2.1 ± 0.33	8	1.9 ± 0.16	8	1.9 ± 0.15	8	2.2 ± 0.45	32	2.0 ± 0.15
11.Z.114.A19	11	3.3 ± 0.20	11	3.7 ± 0.11	11	3.8 ± 0.10	11	3.5 ± 0.37	44	3.6 ± 0.11
11.Z.114.A9	11	2.5 ± 0.21	11	3.6 ± 0.13	11	3.3 ± 0.16	11	2.1 ± 0.25	44	2.9 ± 0.13
A13	5	1.7 ± 0.16	5	2.8 ± 0.05	5	2.6 ± 0.07	5	1.4 ± 0.08	20	2.1 ± 0.05
Agria (3)	3	3.2 ± 0.48					3	3.8 ± 0.12	6	3.5 ± 0.18
Atlantic (2)	6	2.5 ± 0.43					6	1.5 ± 0.28	12	2.0 ± 0.29
Bambino	6	1.9 ± 0.31					6	2.8 ± 0.29	12	2.4 ± 0.09
Cabaret (3)	6	2.3 ± 0.42					6	2.5 ± 0.42	12	2.4 ± 0.29
<b>Cara (4)</b>	18	4.0 ± 0.00	15	4.0 ± 0.00	15	4.0 ± 0.00	18	4.0 ± 0.00	66	4.0 ± 0.00
Chicago	6	1.5 ± 0.17					6	3.1 ± 0.39	12	2.3 ± 0.20
<b>Estima (1)</b>	32	1.0 ± 0.00	29	1.0 ± 0.00	29	1.0 ± 0.00	32	1.0 ± 0.00	122	1.0 ± 0.00
Hermes (3)	6	3.4 ± 0.29					6	2.5 ± 0.46	12	2.9 ± 0.33
Infinity	10	2.0 ± 0.30	10	1.9 ± 0.11	10	1.6 ± 0.15	10	1.2 ± 0.14	40	1.7 ± 0.14
<b>Jelly</b>	11	3.0 ± 0.00	11	3.0 ± 0.00	11	3.0 ± 0.00	11	3.0 ± 0.00	11	3.0 ± 0.00
<i>Lady Claire (2)</i>	6	1.5 ± 0.22					6	1.5 ± 0.22	12	1.5 ± 0.22
Lady Rosetta (2)	6	2.8 ± 0.32					6	2.9 ± 0.45	12	2.8 ± 0.37
Maris Peer (2)	6	2.3 ± 0.46					6	2.6 ± 0.49	12	2.4 ± 0.42
Maris Piper (3)	6	3.9 ± 0.13					6	3.2 ± 0.32	12	3.5 ± 0.14
<i>Markies (4)</i>	6	3.9 ± 0.05					6	3.1 ± 0.43	12	3.5 ± 0.23
Molly	5	2.9 ± 0.31	5	2.8 ± 0.19	5	2.4 ± 0.19	5	2.5 ± 0.07	20	2.7 ± 0.12
Nectar	15	2.1 ± 0.12	15	2.1 ± 0.18	15	2.0 ± 0.18	15	1.8 ± 0.19	60	2.0 ± 0.15
<i>Red Fantasy</i>	8	3.5 ± 0.19	8	3.1 ± 0.10	8	3.0 ± 0.09	8	3.4 ± 0.14	32	3.2 ± 0.08
Saxon (2)	6	2.5 ± 0.39					6	1.8 ± 0.37	12	2.1 ± 0.31
Soraya	21	1.5 ± 0.12	21	1.6 ± 0.09	21	1.5 ± 0.08	23	1.3 ± 0.16	84	1.5 ± 0.07
Tyson	29	1.9 ± 0.13	29	2.4 ± 0.13	29	2.0 ± 0.11	29	2.3 ± 0.18	116	2.2 ± 0.11
Vizelle	6	1.1 ± 0.14					6	2.0 ± 0.44	12	1.6 ± 0.21

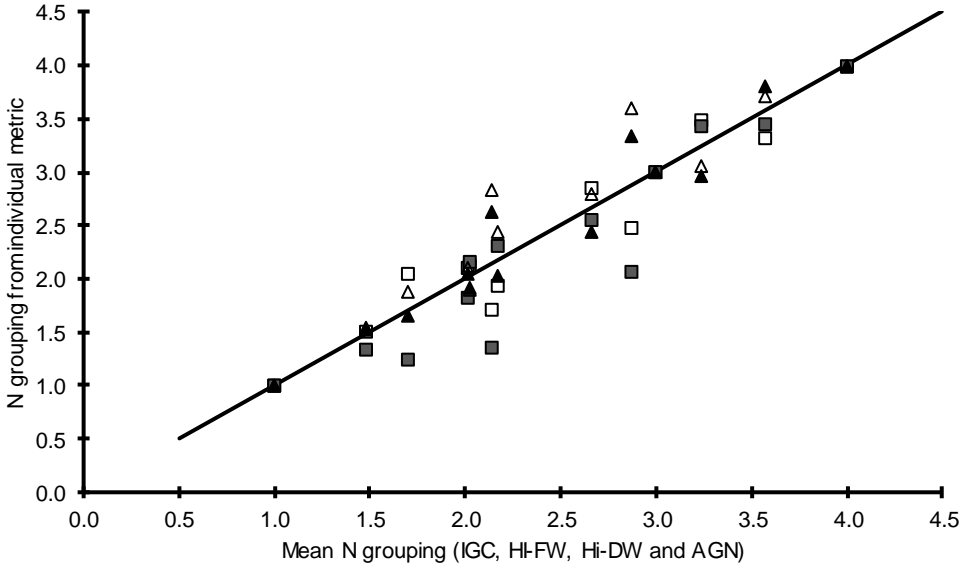
Collectively, the nitrogen grouping data from 2017 to 2019 were analysed to give an indication of the relative performance of each metric and the stability of the estimates of a variety's nitrogen group when assessed at different locations and season. To do this, the N grouping derived for an individual metric was compared with the mean N grouping which was derived from all the metrics used for that variety. At the Cygnet sites in 2017 and 2018 only two, non-destructive, metrics were tested (integrated ground cover and above ground nodes). At the NIAB and Greenvale sites in 2017, 2018 and 2019, metrics based on the assessment of harvest index were also tested. In total integrated cover and node data were obtained for 26 varieties (**Figure 17a**) and the complete suite of metrics were obtained for 13 varieties (**Figure 17b**). These data indicate that, in general, all the individual metrics tend to give estimates of N grouping that are within half a nitrogen group of the collective mean values. Therefore, if resources are limited, reasonably accurate approximations of nitrogen grouping can be made by using only one method and due to its simplicity and rapidity and cost-effectiveness measurement of above ground nodes is the preferred method.

Figure 17. (a) Comparison of N grouping determined by two methods against the mean ranking of the two methods for 26 varieties and, (b) Comparison of N grouping determined by four methods against the mean ranking of the four methods for 13 varieties. Above ground nodes (AGM), ■; integrated ground cover (IGC), □; fresh weight harvest index (HI-FW), △ and dry weigh harvest index (HI-DW), . The solid line is the 1 : 1 relationship.

(a)



(b)



## 5. CONCLUSIONS

This three-year programme has generated much useful data despite challenging field-experimental conditions in 2018. All four candidate metrics have shown themselves useful in allocating varieties into their nitrogen groupings. However, analysis has shown that care needs to be taken in employing the metrics and interpreting the data. For example, analysis has shown that asynchronous emergence in experiments can affect the interpretation of harvest index data. Similarly, varietal measurements of integrated ground cover data derived from “crowd-sourced” commercial data may be compromised due to the very different environmental and management conditions experienced by the crop. In commercial crops and experiments, excess N can also compromise data since these crops will often be defoliated before the onset of natural senescence and, again, this will hinder interpretation of the ground cover data. In general, the N groups derived using the four method are well correlated with each other and are also well correlated with published nitrogen groups. In many cases, the exceptions indicate some possible limitations in the published ranking rather than indicate flaws in the proposed methodology. It would seem sensible that in order to determine the nitrogen grouping of a new variety more than one metric should be used. However, if resources (e.g. seed or labour) are limited then measurement of above ground nodes is recommended since this method has shown itself to be rapid, robust, non-destructive and efficient.

Careful use of the proposed metrics will enable the allocation of a new variety to its N group. Crucially, this process is now objective and follows a clearly defined protocol unlike earlier allocations many of which were based on subjective opinion. Furthermore, if the methodology is used correctly it is possible to estimate the approximate error associated with the allocation (typically  $\pm$  c. 0.5 N groups) and this information will be useful in developing the agronomy package during the commercialisation of a new variety.

## 6. REFERENCES

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## 7. APPENDICES

### 7.1. Use of commercial survey data to determine nitrogen groupings

Earlier work has shown that, all other things being equal, determinate varieties will have less persistent canopies than indeterminate varieties. A component of this project was to collate and analyse data from commercial crops to determine whether it would be possible to infer nitrogen grouping from information on canopy persistence. For this study two data sources were used: the first (shown in **Table 25**) was derived from 391 UK processing crops grown between 2010 and 2016; the second (**Table 26**) was derived from 636 crops that were submitted for crop modelling between 2017 and 2019. The data from the processing crops show that there is some correlation between integrated ground cover and the nitrogen grouping given in the nutrient management guide. However, these data show that commercial measures of canopy persistence are not very discriminatory. For example, Lady Rosetta (Group 2) had a mean integrated ground cover of 6566 %days compared with Markies (Group 4) with a value of 7147 %days. The difference (581 %days) is only equivalent to an extra 6 days at 100 % ground cover. The larger and more recent data set shown in **Table 26** again shows a correlation between nitrogen grouping and canopy persistence (defined as the number of days the canopy is above 50 % ground cover). Collectively, these data show that as the nitrogen grouping increases from 1 to 4, the median canopy persistence increased from 65 to 93 days. However, in some cases the apparent difference between groups is small (for example Innovator, Lady Rosetta and King Edward) and in some cases the mean difference in canopy persistence is the reverse to what might be expected from the nitrogen groupings (for example Pentland Dell and Markies). It is highly likely that the varietal differences in canopy persistence are being obscured by how the commercial crops are managed. The determinate varieties should, on average, be receiving more N fertilizer than the indeterminate and this will have the effect of decreasing varietal differences in canopy persistence. Similarly, most of these crops will either be defoliated to manage tuber size or to hasten skin-set at the end of the season. The decrease in canopy persistence due to defoliation will distort the metrics. For example, Marfona (Group 2) is often used to produce short-season baking potatoes and is often harvested green-top after a relatively short season. Similarly, Maris Peer (Group 2) is used for salad potato production and also has a curtailed season-length to maximise production of small potatoes. Because of this, both of these varieties have median season lengths shorter than that of the chipping variety Innovator (Group 1).

**Table 25. Variation in integrated ground cover in 11 processing varieties. Values in brackets are nitrogen grouping in current Nutrient Management Guide (RB209)**

Variety	Number of examples	Integrated GC (% days)
Lady Claire (2)	23	6459 ± 227.5
Lady Rosetta (2)	105	6566 ± 140.3
Linton	12	6676 ± 359.9
Saturna (3)	52	7125 ± 165.6
Shelford	26	7135 ± 159.2
Markies (4)	6	7147 ± 455.6
VR808	65	7436 ± 96.6
Infinity	5	7460 ± 232.1
Arsenal	37	7488 ± 181.4
Hermes (3)	55	7711 ± 145.8
Brooke	5	8028 ± 221.1

**Table 26. Variation in canopy persistence in 38 varieties grown in 2017-2019. Data are derived from commercial crops**

Variety (number of crops)	Nitrogen grouping in RB209	Mean canopy persistence and S.E. (days)	Median canopy persistence (days)	Upper 95 percentile canopy persistence (days)
Arsenal (n=11)		69 ± 3.5	70	81
Aurea (n=6)		66 ± 6.2	68	85
Belana (n=14)		41 ± 2.2	40	55
Brooke (n=19)		88 ± 2.7	87	105
Chopin (n=10)		64 ± 3.2	64	75
Desiree (n=15)	3	80 ± 2.3	80	91
Electra (n=22)		77 ± 1.1	76	84
FL 2339 (n=10)		63 ± 3.6	65	77
Innovator (n=22)	1	68 ± 2.1	65	82
Ivory Russet (n=27)		73 ± 2.0	75	86
Jelly (n=39)		86 ± 1.4	85	100
Jersey Royal (n=20)		52 ± 1.3	50	65
King Edward (n=15)	3	77 ± 1.7	77	85
Lady Claire (n=5)	2	69 ± 4.8	69	82
Lady Rosetta (n=36)	2	71 ± 2.6	74	88
Lanorma (n=22)		72 ± 10.0	70	84
Leontine (n=5)		71 ± 4.0	75	75
Marfona (n=21)	2	59 ± 1.8	60	72
Maris Peer (n=16)	2	58 ± 2.6	58	75
Maris Piper (n=88)	3	82 ± 1.3	85	101
Markies (n=7)	4	92 ± 4.0	95	104
Melody (n=21)	2	75 ± 2.8	70	96
Nectar (n=61)		80 ± 1.2	80	95
Orchestra (n=7)		66 ± 2.7	63	76
Osprey (n=7)	2	72 ± 2.1	72	79
Pentland Dell (n=5)	3	102 ± 5.0	105	114
Pirol (n=6)		73 ± 2.1	72	80
Red Fantasy (n=10)		73 ± 2.7	75	86
Royal (n=7)	4	87 ± 4.5	94	95
Sapphire (n=10)		82 ± 3.6	87	95
Saxon (n=6)	2	67 ± 2.2	65	74
Shelford (n=11)		79 ± 2.4	80	89
Soraya (n=12)		67 ± 1.8	70	75
Tyson (n=5)		84 ± 1.9	85	89
Vales Sovereign (n=6)	4	88 ± 2.1	90	94
Venezia (n=5)		56 ± 3.7	60	64
Vivaldi (n=9)	2	68 ± 2.4	69	77
VR 808 (n=18)		75 ± 2.3	75	87

It is possible that the effect of defoliation could be minimised by using the upper 95 percentile of season length since this may give a better estimate of a variety's potential season-length. On average, when compared with the median season length, the 95 percentile season length

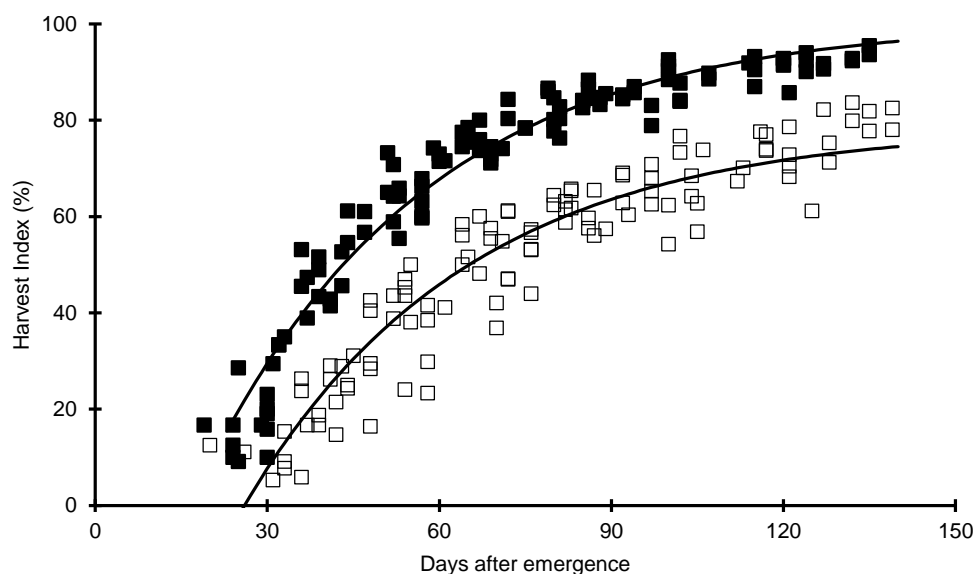
was c. 11 days longer. However, varietal comparisons using season lengths based on the 95 percentile will still be affected by nitrogen application rate and other confounding factors known to affect canopy growth and duration (for example compaction, over- or under-watering and PCN). In conclusion, in the absence of other data, “crowd sourced” canopy data could be used to crudely estimate N groupings but these data are compromised by many confounding factors and care should be taken in their use.

## **7.2. Review of Harvest Index Methodology**

A candidate metric used in this study is the harvest index which, for the purposes of this project, is defined as the total yield of tubers as a percentage of the total (haulm and tuber) yield. The purpose of this review is to re-analyse some archive data to better understand the limitations and benefits of this method.

The data set used for this analysis was derived from the British Potato Council (BPC) Reference Crop project that ran from 1998 to 2002 (see for example Firman *et al.* 2001). In each year crops of Cara (determinacy group 4), Estima (1), Lady Rosetta (2) and Russet Burbank (3) were grown in four of five diverse locations each year from a common stock of seed. As far as practical, the crops were planted and sampled on similar dates and were monitored and sampled using the same protocol at each site. At some sites a comparison was made between rain-fed and irrigated crops. Experimental designs varied from site to site, but each treatment combination was replicated four times. Typically, at each site crops were sampled on four occasions during the growing season and, at each harvest, data were collected that enabled the harvest index to be calculated. For this analysis, the data were restricted to remove any samples where the tuber yield (and therefore harvest index) was 0. For ease of subsequent analysis, it was further assumed that for all four varieties the shape of the curve relating harvest index to time after emergence was the same and curves differed only in their displacement on the ‘y’ axis. Figure 18 shows the relationship between harvest index and time after emergence for Cara and Estima (Lady Rosetta and Russet Burbank have been omitted from the graph for clarity).

**Figure 18. Variation in harvest index (based on dry matter) with days after emergence for Cara, □ and Estima, ■. The fitted lines are described in the text. Data are derived from BPC Reference Crops 1998-2002.**



Using parameters derived from the fitted exponential curves, Table 27 tabulates estimates of harvest index for a range of days after emergence. These data indicate that use of harvest index should be readily able to discriminate between, for example, Cara and Estima or Estima and Russet Burbank. However, the difference between Estima and Lady Rosetta was always small (c. 2 percentage points) and using harvest index as a metric for determinacy would have placed these two varieties into the same group. It is possible that, in the past, Lady Rosetta was misallocated to Nitrogen Group 2 work in 2018 will test this using both historic and new experimental data. The experiment with Greenvale AP showed a nine day variation between the earliest emerging variety (Tyson, 22 May) and the latest (Red Fantasy, 31 May). If it is assumed that Tyson is more determinate than Red Fantasy and that the sampling date was based on the average date of 50 percent emergence for the experiment (25 May) then not accounting for the difference in emergence will decrease the observed harvest index by c. 8-10 percentage points and this may be sufficient to obscure real differences in varietal determinacy. Therefore, experiments that use harvest index as metric of varietal determinacy should, ideally, have synchronous emergence. However, the relation shown in Table 27 may be used to correct for differences in emergence dates.

**Table 27. Estimates of harvest index for four varieties derived from fitted exponential curves. Data are derived from BPC Reference Crops 1998-2002.**

	Cara	Estima	Lady Rosetta	Russet Burbank
Number of samples	108	114	118	109
Days after emergence				
45	30	52	51	41
50	36	58	57	47
55	41	63	62	52
60	46	68	66	56
65	50	72	70	60

### 7.3. Development of an industry-friendly protocol to determine nitrogen grouping

An objective of the program was to devise a draft protocol that could be tested and refined in years 2 and 3. This draft protocol is shown in Table 28. This protocol recognizes that to be adopted by industry it must be: reliable, simple, must not rely on sophisticated equipment, must recognize that, in some cases, the experimental area may be unreplicated and may comprise a single row of few plants due to limitations in seed supply. Where seed supply is limited, destructive harvesting (e.g. to measure mid-season harvest index) may not be appropriate. In some cases, it may also not be possible to include reference varieties of known determinacy and in these cases a new variety will need to be compared against an absolute scale of, for example, main-axis above ground nodes rather than a relative scale created using known reference varieties. A special case of varietal data supplied without matching reference data would be 'crowd-sourced' ground cover data which, for many varieties, may be the only information available.

**Table 28. Draft protocol to measure key metrics of varietal determinacy**

Variable	Comment
Nitrogen application rate	Relatively low to ensure that the most indeterminate variety has started to senesce at the end of the experiment
Soil type	As uniform an area as possible with similar texture, organic matter content and rooting depth
Nutrition, irrigation and crop protection	Adequate supply of P, K and Mg; irrigation scheduled to ensure limiting soil moisture deficits are not exceeded and crop protection applied according to best practice
Seed	Ideally, high-health seed. For multiple variety experiments the seed should be of a similar size, chronological and physiological age and planted at a similar depth to encourage synchronous emergence

**Table 29. Effect of seed supply on metrics and experimental design**

Seed supply	Design and minimum seed requirement per variety	Metrics
Limited	Single plots of guarded plants (e.g. three row plot with observations made on middle row). No destructive sampling. 1 replicate x 3 rows x 6 plants = 18 tubers	Weekly ground cover and above ground nodes (see Materials and Methods)
	Multiple plots that are replicated and randomized. No destructive sampling. 4 replicates x 3 rows x 6 plants = 72 tubers	Weekly ground cover and above ground nodes (see Materials and methods)
Ample	Multiple plots that are replicated and randomized. With a mid-season sampling at 55 days after emergence 4 replicates x 4 rows x 16 plants/row = 256 tubers	Weekly ground cover, above ground nodes and harvest index at 55 days after emergence (see

## **7.4. Measuring the number of leaves in potato as an indicator of nitrogen group**

### **7.4.1. Background**

Nitrogen (N) fertilizer recommendations for potatoes are based, in part, on the intended length of the growing season and the Nitrogen Group of the variety being grown (AHDB Nutrient Management Guide (RB209), Section 5 Potatoes May 2017). Nitrogen Groups vary from Group 1 (very determinate) to Group 4 (very indeterminate) and, for a given season length, a Nitrogen Group 1 variety may need twice the N fertilizer application when compared with a Group 4. Giving the wrong amount of N fertilizer to a potato crop often results in loss of yield and may also affect tuber dry matter concentration. It is important that as new varieties are released, their nitrogen requirements are known as soon possible to help ensure successful commercialization.

Earlier work funded by Cambridge University Potato Growers Research Association (CUPGRA) and a recent Agricultural and Horticultural Development Board (AHDB) project (Project Number 11140044) has shown that counting the number of leaves on a mainstem of potato plant can be used as an indicator of the Nitrogen Group. This method is simple, rapid and is suitable for use where stocks of a new variety are limited.

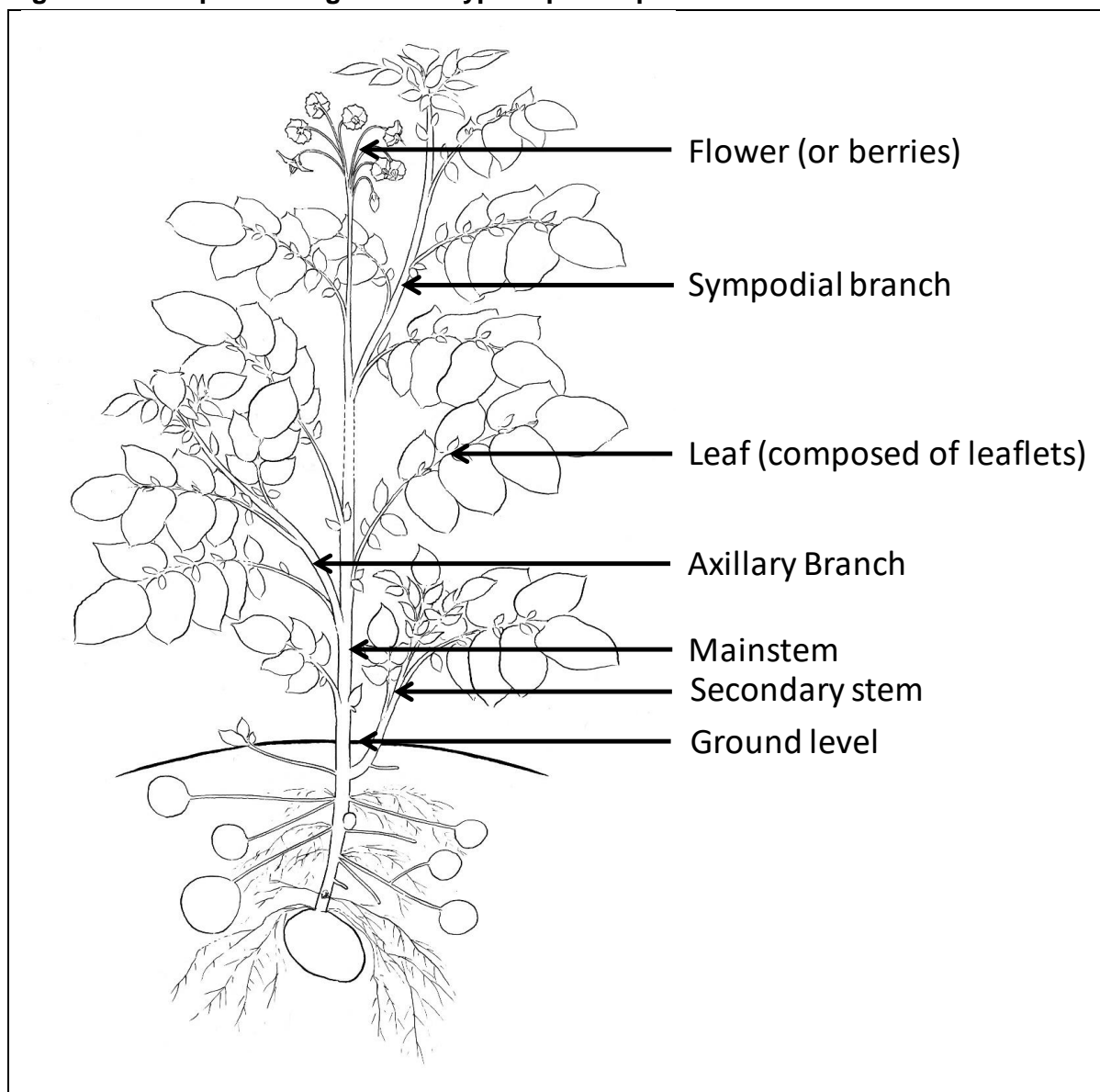
### **7.4.2. Methodology**

Although counting the number of leaves is both simple and quick and may be non-destructive if leaves are counted *in-situ*, it is important that this protocol is followed so that leaves are counted in a consistent way. It will be important to be able to identify the main-stem, the first flower that forms on the mainstem, the sympodial branch that continues the main-stem and then subsequent sympodial branches and flowers (the 'main-axis' of the plant). To work out the Nitrogen Grouping of a new variety it is always best to grow it alongside other, contrasting, varieties of known Nitrogen Grouping under similar conditions. There is a worked example below to show how you convert the number of leaves into an estimate of the nitrogen grouping.

### **7.4.3. The structure of the potato stem**

The basic structure of the potato plant is shown in **Figure 19**. To count the number of leaves accurately, it will be important to identify the main-stem, the first flower forming on the mainstem, the sympodial branch that continues the main-stem from just below the flower and then subsequent tiers of sympodial branches and flowers. For some very determinate varieties (Nitrogen Group 1) development of the plant stops at flowering and there is no sympodial branch. Conversely, very indeterminate varieties may produce several tiers of sympodial branched and flowers. It is important that you only count the number of leaves on the main stem and subsequent sympodial branches – **do not** count leaves on axillary branches.

**Figure 19. Simplified diagram of a typical potato plant.**



#### **7.4.4. Timing of the measurement**

The method relies on counting the **maximum** number of leaves produced by the variety and therefore counting is best done when the crop is just starting to senesce **naturally** and leaf production/expansion has ceased.

#### **7.4.5. Selection of stems**

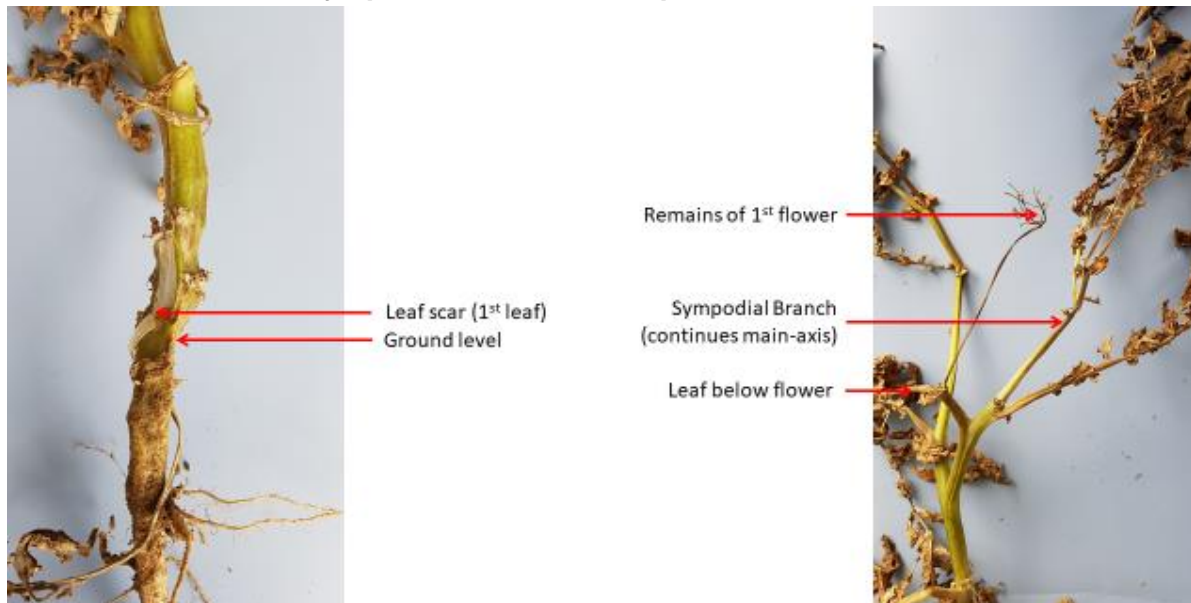
Select five individual stems from five typical plants per crop. Plants of the same variety should surround the plants you select and avoid diseased plants or plants next to wheelings. Carefully pull up the individual mainstems taking care not to break the stem or break off leaves.

#### **7.4.6. Counting the number of leaves**

We are only interested in counting leaves on the main-axis of the plant. Starting at soil level (indicated by a change in colour on the mainstem, see **Figure 20**), count the number of leaves on the mainstem up to the first flower. To maximize light absorption, the leaves are arranged

in spiral around the main axis with an angle of about  $138^\circ$  between leaves. Therefore, on average, there are about five leaves in two complete turns about the stem. It is likely that the leaves just above ground level will have died at the time of sampling and in this case count the scar where the leaf was attached instead (**Figure 20**). Similarly, it is also possible that at the time of counting the flower will have fallen off, however, by careful counting, it should still be possible to estimate where the flower was located (**Figure 20**).

**Figure 20.** Left hand image shows the position of leaf scar and ground level (variety Lady Claire). The Right hand image shows the remains of the flower and the sympodial branch – note that the sympodial branch develops from two leaves below the flower.



The sympodial branch is typically located two leaves below the flower, - but this can vary from one leaf up to three or four. Irrespective of where the sympodial branch is located, count **all** the leaves on the mainstem to the first flower then add on the number of leaves on the sympodial branch(es) (**Figure 21**).

As you get toward the top of the plant the leaves will get smaller and more closely bunched together. Only count leaves that are longer than 5 mm. For guidance, there are typically 18 to 21 leaves from ground level to the first flower, but in some varieties it may be only 10 to 12.

**Figure 21.** Picture showing position of sympodial branch in relation to 1st flower and location of 2nd flower on the sympodial branch.



### 7.4.7. Processing the data

An example of the calculation used to estimate the Nitrogen Grouping of a new variety if it grown alongside varieties of known nitrogen grouping is shown in the table below.

Varieties grown in similar conditions	Nitrogen Group	Number of main-axis leaves > 5 mm (mean of five stems)	Change in number of leaves per Nitrogen Group	Difference in the number of leaves between the New Variety and Estima	Difference in number of leaves converted to change in Nitrogen Group	Estimate of Nitrogen Group of New Variety	Rounding value to nearest whole Nitrogen Group
Markies	4	38	$= (38 - 19) \div (4 - 1)$ $= 6.3$				
Estima	1	19					
New variety	Unknown	24		$= (24 - 19) = 5$	$= (5 \div 6.3) = 0.8$	$= (1 + 0.8) = 1.8$	2

**7.5. Existing and suggested nitrogen grouping for the UK's top 50 varieties by area. Confidence ranges from 1 (low confidence e.g. few data, unreplicated experiments or commercial surveys) to 3 (high confidence e.g. large data set, replicated experiments etc.)**

2018 area rank	Variety	Current N grouping in RB209	New N Grouping and relative confidence		2018 area rank	Variety	Current N grouping in RB209	New N Grouping and relative confidence	
1	Maris Piper	3	3	3	26	Russet Burbank	3	3	3
2	Markies	4	4	3	27	Ramos	-	-	-
3	Maris Peer	2	2	3	28	Hermes	3	3	3
4	Melody	2	2	3	29	Arsenal		3	3
5	Nectar	-	2	3	30	Jazzy		2	1
6	Innovator	1	1	3	31	Fontane		3	1
7	Taurus	-	2	1	32	Accord	1	1	2
8	Sagitta	-	2	1	33	Shepody	2	2	3
9	Royal	4	4	3	34	Cabaret	3	3	2
10	Lady Rosetta	2	2	3	35	Electra		4	3
11	Rooster	3	3	3	36	Lady Claire	2	2	3
12	Pentland Dell	3	3	3	37	Osprey	2	2	1
13	Cultra	3	3	3	38	Shelford		3	3
14	Estima	1	1	3	39	Daisy	3	3	1
15	Marfona	2	2	3	40	Premiere	1	1	3
16	Agria	3	3	2	41	Jelly		3	3
17	Charlotte	2	2	3	42	Mozart	2	2	2
18	King Edward	3	3	3	43	Eurostar		3	1
19	Challenger	-	-	-	44	Orchestra	2	2	2
20	VR 808	-	2	3	45	Wilja	2	2	2
21	Brooke	-	4	3	46	Cara	4	4	3
22	Gemson	-	-	-	47	Harmony	2	2	2
23	Desiree	3	3	3	48	Saphire		2	1
24	Lanorma	-	2	1	49	Performer		3	1
25	Saxon	2	2	2	50	Manhattan	-	-	-

No reliable data exist for Challenger, Gemson, Ramos & Manhattan

## **8. ACKNOWLEDGEMENTS**

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