Project title:	The Application of Precision Agronomy to UK Production of Narcissus
Project number:	CP 103
Project leader:	Rob Lillywhite, University of Warwick
Report:	Annual, October 2014
Previous report:	N/A
Key staff:	Rob Lillywhite Dr Rosemary Collier
Location of project:	University of Warwick
Industry Representative:	Mark Clark, Grampian Growers Ltd., Logie, Montrose, Angus, DD10 9LD
Date project commenced:	30 September 2013
Date project completed (or expected completion date):	30 September 2016

© Agriculture and Horticulture Development Board 2015. All rights reserved

DISCLAIMER

AHDB, operating through its HDC division seeks to ensure that the information contained within this document is accurate at the time of printing. No warranty is given in respect thereof and, to the maximum extent permitted by law the Agriculture and Horticulture Development Board accepts no liability for loss, damage or injury howsoever caused (including that caused by negligence) or suffered directly or indirectly in relation to information and opinions contained in or omitted from this document.

Copyright, Agriculture and Horticulture Development Board 2015. All rights reserved.

No part of this publication may be reproduced in any material form (including by photocopy or storage in any medium by electronic means) or any copy or adaptation stored, published or distributed (by physical, electronic or other means) without the prior permission in writing of the Agriculture and Horticulture Development Board, other than by reproduction in an unmodified form for the sole purpose of use as an information resource when the Agriculture and Horticulture Development Board or HDC is clearly acknowledged as the source, or in accordance with the provisions of the Copyright, Designs and Patents Act 1988. All rights reserved.

AHDB (logo) is a registered trademark of the Agriculture and Horticulture Development Board.
HDC is a registered trademark of the Agriculture and Horticulture Development Board, for use by its HDC division.
All other trademarks, logos and brand names contained in this publication are the trademarks of their respective holders. No rights are granted without the prior written permission of the relevant owners.

[The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.]

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

James Syrett

PhD Student

University of Warwick

Signature .... Date ....

[Name]

[Position]

[Organisation]

Signature .... Date ....

Report authorised by:

[Name]

[Position]

[Organisation]

Signature .... Date ....

[Name]

[Position]

[Organisation]

Signature .... Date ....

© Agriculture and Horticulture Development Board 2015. All rights reserved

CONTENTS

© Agriculture and Horticulture Development Board 2015. All rights reserved

GROWER SUMMARY

Headline

- A survey of commercial growers was carried out in early 2014. Thirty-one growers and cooperatives responded.
- The project started in October 2013 and the field trials were established in four locations during the period July to October 2014.

Background

The UK narcissus industry has fallen behind other arable and horticultural sectors in terms of the technology it employs, despite leading the world in terms of its output. The heyday of narcissus research came in the 1950s-1980s, mainly courtesy of the Rosewarne and Kirton research stations, when many of the agronomic parameters affecting yield and crop quality were established, as well as refinements in crop handling and pest and disease control. However, changes in production practices, markets and varieties have rendered much of the evidence and recommendations obsolete. The findings of this period need to be examined, and if necessary revised, to reflect current practice. It is hoped that advances in precision agronomy from other horticultural sectors, e.g. potatoes and onions, will be able to address some of the problems facing the industry, or simply boost productivity while lowering costs – a necessary intervention in a time when production costs are rising, but retailers are static on pricing.

Summary

Field trials were established to examine a number of different production approaches including bulb density, planting depth and bulb orientation.

- Bulb density – Research in the 1970s examined a wide range of experimental densities (7.7 up to 78 t/ha) and established that the optimum density at planting was around 17 t/ha for flower production and 10 t/ha for bulb mass increase. This project is using a narrower range (5 to 27 t/ha) to examine if those recommendations remain valid for current commercial practices.
- Planting depth - Deeper planting has been proven to benefit the crop, but must be traded off against ease of lifting. The benefits of deep planting will be re-assessed throughout this project.
- Bulb orientation - The effects of placing the bulb (either upright or inverted, compared to the random orientation currently used) will also be assessed to

© Agriculture and Horticulture Development Board 2015. All rights reserved

establish any benefits that could be gained from developing a precision planting system.

- Fertiliser placement – Precision placement of fertilisers is being used by some growers and anecdotal evidence suggests that fertiliser savings of around 30% are possible. This will be investigated experimentally to inform a cost-benefit analysis for the technology in its various forms.

A number of key targets have been identified for precision technologies that are likely to benefit daffodil growers, particularly precision planting (planters able to distribute the bulbs evenly); screening of bulbs for pests and diseases; and monitoring levels of crop protection products during hot water treatment. Some existing solutions already used in other sectors, such as the onion, apple and potato industries, will be evaluated on their suitability for ornamental bulbs. Others will be developed from scratch, based on devices already used in horticulture, medical diagnostics, bulk goods handling and more.

Each of the precision solutions conceived will be tested as far as possible and cost-benefit analyses conducted to establish which are most likely to boost grower productivity.

This project examines how precision agronomy can be applied to narcissus production. The aspects of production being investigated include:

- The effects of crop density and depth on bulb stocks and cut flower production;
- Reductions in fertiliser usage by 30% by using precision placement;
- Identify precision technologies and methods to maximise productivity, reduce costs and meet variable demand more reliably;

This report covers the first year of the project; October 2013 to September 2014 and includes details of the activities undertaken. In general terms, the first year was devoted to gaining an understanding of the industry, so that experiments can be tailored to these standards and practices, and establishing the field trials. The main experimental data will follow in the second and third years – the products of four sets of field experiments, both at the Warwick Crop Centre and on growers' holdings in Cornwall, Lincolnshire and Aberdeenshire.

© Agriculture and Horticulture Development Board 2015. All rights reserved

SCIENCE SECTION

Introduction

The UK narcissus industry lags behind other arable sectors in terms of the technology it employs, despite leading the world in terms of its output. The heyday of narcissus research came in the 1950s-1980s, mainly courtesy of the Rosewarne and Kirton research stations, when many of the agronomic parameters affecting yield and crop quality were established, as well as refinements in crop handling and pest and disease control. The findings of this period need to be examined, and if necessary revised, to reflect changes in production practices, markets, varieties and the changing climate. For example, The UK currently produces a surplus of bulbs, with the domestic market for bulb sales contracting, though some growth in overseas sales. Most growers subsequently must place more emphasis on cut flower production. Preferences in the market are changing, too, with the USA gradually ordering larger and larger size grades of bulbs. It is expected that precision solutions will be able to solve some of the problems facing the industry, or simply boost productivity while lowering costs – a necessary intervention in a time when production costs are rising, but retailers are static on pricing.

This report covers the first year of the project; October 2013 to September 2014 and includes details of the activities undertaken. In general terms, the first year was devoted to gaining an understanding of the industry, so that experiments can be tailored to these standards and practices, and establishing the field trials. The main experimental data will follow in the second and third years – the products of four sets of field experiments, both at the Warwick Crop Centre and on growers' holdings in Cornwall, Lincolnshire and Aberdeenshire. An audit was conducted to gauge how the industry currently conducts its growing year and the specific varieties, crop protection products and machinery employed. It was also important to survey which precision technologies the growers think will most benefit their production.

The audit did produce one interesting observation which was that bulb orientation at planting has no effect on subsequent growth as bulbs are said to right themselves when growing. Given the influence that this might wield on yield and quality, an experiment was designed to observe this, and to deduce the mechanism by which it occurs. Narcissus have been shown to have contractile roots capable of pulling the bulbs deeper into soil. The expectation (or hypothesis) was that bulbs planted sideways or fully inverted would use these roots or else deform the bulb to right the growing shoot.

© Agriculture and Horticulture Development Board 2015. All rights reserved

In order to provide familiarisation with precision technology and techniques, visits were made to a number of agriculture events (e.g. CropTec in October 2013 and November 2014). These provided a wealth of information about existing precision technologies on the UK market, although they are mainly cereal- and brassica-centric. Soil nutrient mapping is a well-established practice (already indirectly employed by some growers), and a theoretical exploration of its benefits will form a part of my thesis. Yield mapping for potatoes has recently been developed and could be applied to narcissus, though this only measures yield mass and not size grades. Crop canopy colour measurement (by aerial drones or surface probes) as a measure of overall crop health is already available for wheat and barley, and should easily be adapted to narcissus.

Materials and methods

Observations of Self-righting and Depth Adjustment in Narcissus Bulbs

Glass-fronted plant growth tanks (‘rhizotrons’) were supplied by the University of Warwick. These were filled with Erin brand topsoil (compost and loam mixture) to a depth of 45cm. Bulbs of Narcissus ‘Barenwyn’ and ‘Recurvus’ were purchased from B&Q, and one bulb was planted on the surface of the growing medium in each rhizotron, upright, inverted or sideways. Another 10cm of topsoil was added to each tank and watered to saturation. After allowing the growing medium to settle, the starting level of the base of the bulb was marked on the glass with a grease pencil, along with the direction of the bulb neck. The rhizotrons were kept in a glasshouse at ambient temperatures and watered to saturation weekly. The experiment ran from 14 February to 14 April 2014. The roots were photographed weekly for nine weeks, and the bulbs were finally excavated and examined after washing.

Grower Audit

An online survey for growers was established using SurveyMonkey™, and distributed via email to as many growers as possible, either by personal contact or through HDC. The survey requested information on the scale of each company’s operations, the principle varieties used, bulb handling practices and asked for growers’ opinions on which problems they would most like solved and which precision technologies would be of most interest. Growers were not obliged to answer all the questions.

© Agriculture and Horticulture Development Board 2015. All rights reserved

Effects of Depth, Density and Bulb Orientation on Growers' Holdings

Three field trials were established on commercial growers' holdings in August and September 2014: Cornwall (soil type: stony, heavy clay), Lincolnshire (soil type: silt) and Aberdeenshire (soil type: loamy clay). Bulbs of Narcissus 'Dutch Master' for the trials were sourced from commercial growers in the same region, to reduce seasonal effects on the timing of the flowers. Bulbs were planted into grower-made ridges at depths and densities as follows:

Treatment	Depth to Base of Bulbs (cm)	Density (t ha^{-1})	Bulb Orientation
Control	15	17	Random
1	10	17	Random
2	20	17	Random
3	15	12	Random
4	15	22	Random
5	15	27	Random
12*	15	17	Upright
13*	15	17	Inverted

Table 1. Treatments Applied to Field Trials on Growers' Holdings. *NB: Treatments 6-11 are not used in these trials, but are used in counterpart trials at Wellesbourne (See Appendix 2).

Random orientation was created by simply dropping the bulbs in from a height of 0.5m – representative of current industrial planting. Orientated bulbs were similarly scattered, then turned upright or inverted by hand. Soil was backfilled against three depth gauges placed along the ridge and gently firmed until the required depth was achieved. Each treatment was replicated 3 times in a randomised complete block design. The yield and quality of both flowers and bulbs will be assessed over the next two years. Fertilisation and crop protection will be administered by the grower in accordance with their own practices. Results will start to be collected in spring 2015.

Field Experiments at Warwick Crop Centre

Field experiments were established at the Warwick Crop Centre (soil type: sandy loam) in September and October 2014. They will investigate effects of depth and density for six varieties ('Carlton' –'C', 'Dutch Master' – 'DM', Standard Value' – 'SV', 'Golden Ducat' – 'GD', 'Ice Follies' – 'IF' and 'Actaea' – 'A'), the effect of bulb orientation and seasonal

© Agriculture and Horticulture Development Board 2015. All rights reserved

covering for three varieties (‘C’, ‘DM’ and ‘SV’) and the effects of fertiliser placement, irrigation and the storage temperature and time after hot water treatment (HWT) for just one variety (‘C’). Results will start to be collected in spring 2015. See Appendix 2 for the experimental layout.

Results

Observations of Self-righting and Depth Adjustment in Narcissus Bulbs

No evidence was observed of the bulbs self-righting, nor of contractile roots pulling the bulbs deeper into the growing medium. Inverted bulbs simply grew a shoot that curved round and headed upwards against gravity. Some sideways or inverted bulbs showed roots growing between the bulb scales or under the tunic and breaking out of the side of the bulb.

© Agriculture and Horticulture Development Board 2015. All rights reserved

Figure 1. Clockwise from top left: Upright bulb with normal root and shoot orientation; sideways bulb showing bent shoot; inverted bulb showing 180˚ curved shoot; inverted bulb showing affected shoots; root growth from between scales; trapped roots beneath tunic.

Grower Audit

Thirty-one growers responded to the audit carried out in 2013/2014. It is estimated that this response rate accounts for 78% of UK growers and represents an area of 3,581ha of commercial holdings (c88% of UK area).

In overall terms, the response rate is adequate/good and we are comfortable that the sample size is sufficiently large to provide robust results. Data is fairly complete for the Cornish and Grampian growers, but slightly lacking for the Fens area. Growers were not obliged to answer all the questions, so the number of responses for each question varies.

The results reveal many orders of magnitude in the scale of production between growers, ranging from over 1,100 ha down to just 2 ha for one grower for whom daffodils are a minor

© Agriculture and Horticulture Development Board 2015. All rights reserved

crop. Cornwall presents the largest variation in grower size, while the growers of the Grampian co-operative in Scotland are small, but much more uniform in size.

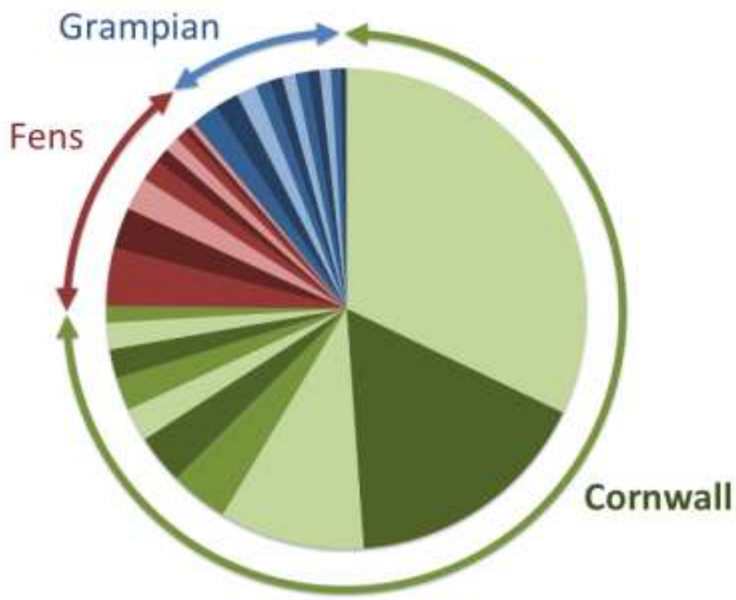


Figure 2. Size Distribution of Growers in the Three Main Regions. Green, red and blue sectors represent Cornish, Fens and Grampian sites respectively. Based on survey responses. Note that companies may own land in more than one region.

Of key interest was the selection of varieties planted. The survey asked for at least one early, middle and late variety for each grower. 'Standard Value' was the most universal late variety across all three regions. Similarly, 'Golden Ducat' is the double variety of choice in all three regions. Early varieties were more complicated, with 'Tamara' the outright favourite variety in Cornwall, and popular in The Fens, but not grown at all in Scotland. 'Dutch Master' was ultimately selected as a compromise, bringing the added benefit of a wealth of existing literature for the variety. Mid-season varieties were least cohesive, with growers planting a wide and variable selection. 'Carlton' was ultimately selected, which despite waning popularity was relatively common and still makes up a large proportion of many farm stocks for historical reasons. 'Carlton' also has a large volume of previous research behind it.

'Ice Follies' was selected as a ubiquitous variety driven by bulb sales (including in mixtures), and 'Actaea' was selected to test the claim that different varieties require different agronomy – division 9 narcissus said to require lower growing densities. Although growers were given the option to name varieties not on the list provided, this did not throw up any widely popular choices.

One grower explained that a minimum of around 16 varieties is needed for continuous, season-long flower production, with another 16 required as backup. The audit revealed most growers do grow a wide selection (although they were only asked to name a maximum of 10). Only one large-scale grower seems to defy this, growing just four varieties.

Saleable bulb grades peaked around the 10-12 and 12-14 cm grades, as expected. The proportions of planted grades was closely matched between Cornwall and Scotland, dipping

© Agriculture and Horticulture Development Board 2015. All rights reserved

in relation to the preferred sale grades, but Fenland growers reported a more uniform mixture of planted grades, contrary to expectations. Four Cornish growers and two Fenland growers said they discarded bulbs smaller than 8cm, compared to just one Grampian grower.

Windrowing as an initial drying method for lifting bulbs is used (weather permitting) in Cornwall and Grampian, but rarely in the Fens, where the soil is seldom dry enough. All twenty-seven respondents reported using a wooden bin system for drying after lifting, while nine also reported using a drying floor.

The audit revealed general agreement on some variables, such as the typical planting depth (c15 cm to the base of the bulb) and some aspects of bulb handling, such as drying times and temperatures. There was notable variation between growing regions in terms of the mixture of varieties planted, HWT temperatures used, bulb grades to be sold or planted and the overall business model in terms of focus on flowers or bulbs.

Fenland growers all used the standard 44.4˚C HWT, though only two reported using partial pre-warming to protect flower quality. All Grampian region bulbs are hot water treated by the 'Grampian Growers' co-operative, at 47˚C, following a 30˚C pre-warm and 3-hour pre-soak at the same temperature. The story in Cornwall is more complicated with growers using a range of HWT temperatures, and sometimes all possible regimes on one site. Not all growers use a pre-soak before HWT at higher temperatures, and one that does admits to using a 1-hour soak, rather than the recommended 3 hours.

Bulb drying time after HWT varied greatly, from zero when possible to up to 45 days, but typically around 5 days. Most growers use ambient temperatures of forced air for this, but one grower uses 35˚C. It is also possible that bulbs are dried at elevated temperatures accidentally.

Planting depth did vary, with growers expressing answers differently, but overall, two rough camps emerged, one planting 15cm (6") and one planting 20cm (8"), expressed as depth to the base of the bulb. Shallower planting is more common in Cornwall, where soil is shallow and too stony to plough deeply. Most growers (22 out of 27) said they regularly conduct soil nutrient analyses before planting, although many do this for other crops in their rotation.

Primary industry concerns are control of basal rot, precision planting in terms of distribution of bulbs, efficient drying of bulbs and separation of clods and stones. Fertiliser placement is of interest in Cornwall, but considered less important elsewhere.

The full results of the audit will form the basis of a separate chapter in the finished thesis.

© Agriculture and Horticulture Development Board 2015. All rights reserved

Discussion

The results of the rhizotron trial should not lead to the conclusion that bulbs do not self-right in soil – the experiment may not have covered sufficient time or may not replicate field conditions. More work on the effects of bulb orientation will be established in field experiments, including observations as to whether the bulbs have self-righted. The observation that roots may grow through the bulb upon inverted planting may have implications for infection by soil pests and pathogens. It may also restrict root nutrient uptake, resulting in reduced yields. This will be tested over the next two years in the field.

The audit results reveal little commonality between growers and between growing regions. It was originally hoped that this project would establish a growing model for all growers to follow but this now looks unlikely. Given the variation in practices that exists between (and within) different growing areas, it will prove a challenge to make advice and recommendations that would be universally adopted, given the differences between flower- and bulb-focused production, and the massive disparity between the scales of operation. It seems likely that this project may introduce *more* variation (in the short term, at least) – some growers will be able to implement new practices sooner than others. This is influenced by expiration of growers' current setups (it does not usually make good business sense to replace an already new system or machine), economic circumstances (rising fertiliser costs are more likely to affect large growers sooner than small ones) and geographical limitations (irrigation might never be beneficial to growers in the Fens, where the water table is usually close to the surface) amongst other factors. Ultimately, however, this project should yield information which is universally applicable for narcissus production in any growing situation.

© Agriculture and Horticulture Development Board 2015. All rights reserved

APPENDIX 1

Audit Questions

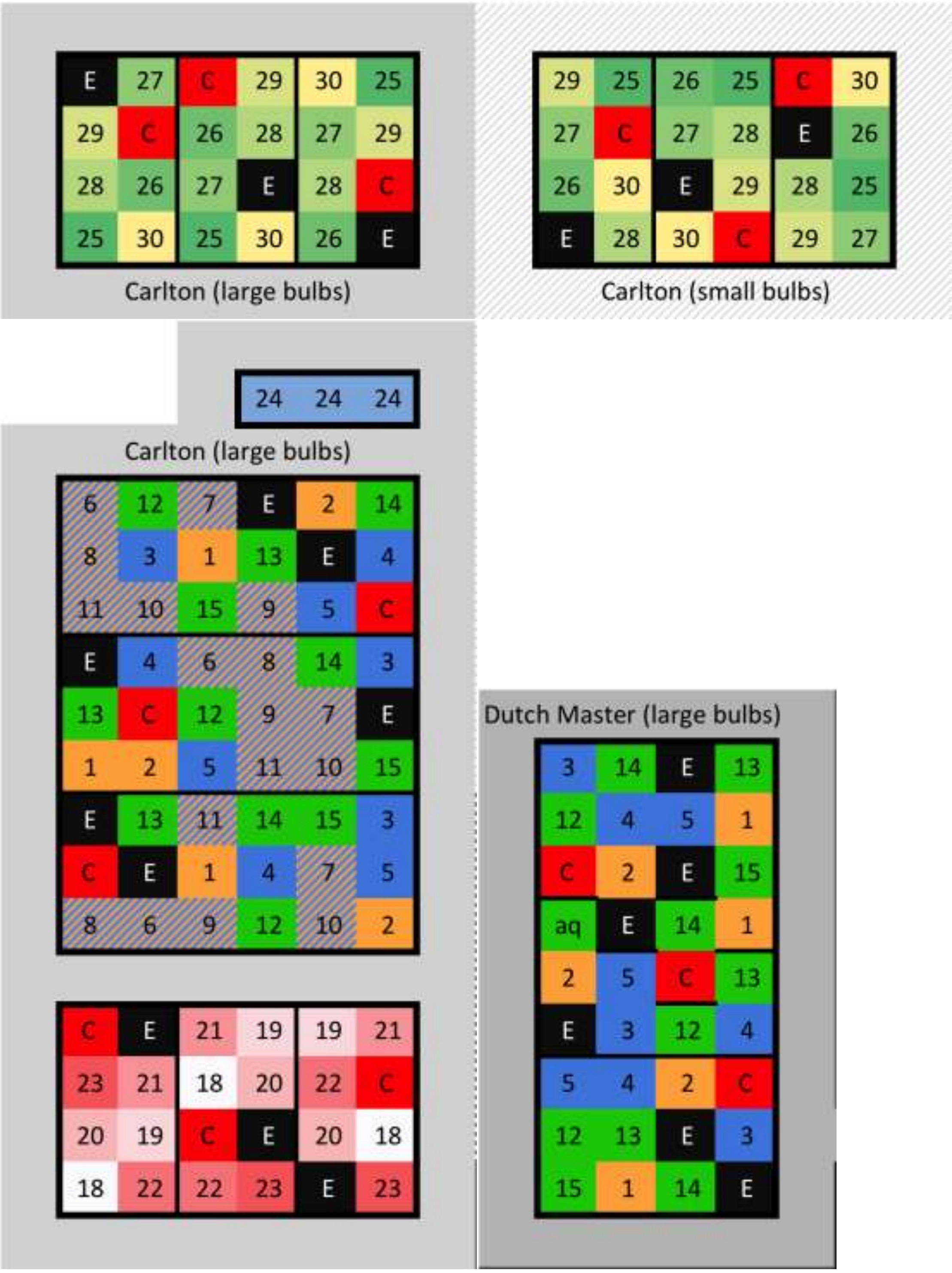
[See accompanying PDF]

© Agriculture and Horticulture Development Board 2015. All rights reserved

APPENDIX 2

Wellesbourne Field Trial Layout

(Relative positions not shown)



© Agriculture and Horticulture Development Board 2015. All rights reserved

Standard Value (large bulbs)

5	14	E	E
1	12	4	15
13	3	C	2
15	C	2	1
3	14	5	E
13	E	12	4
1	5	15	14
E	4	2	3
E	13	12	C

24	24	24

Carlton (small bulbs)

C	2	1
4	5	3
1	4	5
2	3	C
4	1	C
2	5	3

Ice Follies (small bulbs)

2	5	1
4	C	3
C	2	5
3	1	4
3	5	4
1	C	2

Actaea (small bulbs)

5	3	2
C	1	4
5	4	3
1	2	C
C	4	3
2	5	1

Golden Ducat (large bulbs)

5	3	4
C	1	2
2	5	3
1	C	4
1	5	C
4	2	3

16

cv3	cv1	cv2
cv1	cv2	cv3
cv2	cv3	cv1

17

cv2	cv3	cv1
cv3	cv1	cv2
cv1	cv2	cv3

cv1 = Dutch Master

cv2 = Carlton

cv3 = Standard Value

© Agriculture and Horticulture Development Board 2015. All rights reserved

Key:

Number	Depth	Density (large bulbs)	Density (small bulbs)	Treatment
C	15cm	17t/ha	10t/ha	CONTROL, bulbs tumbled, broadcast fertiliser according to DEFRA guides.
1	**10cm**	17t/ha	10t/ha	
2	**20cm**	17t/ha	10t/ha	
3	15cm	**12t/ha**	**5t/ha**	
4	15cm	**22t/ha**	**15t/ha**	
5	15cm	**27t/ha**	**20t/ha**	
6	**10cm**	**12t/ha**	**5t/ha**	
7	**10cm**	**22t/ha**	**15t/ha**	
8	**10cm**	**27t/ha**	**20t/ha**	
9	**20cm**	**12t/ha**	**5t/ha**	
10	**20cm**	**22t/ha**	**15t/ha**	
11	**20cm**	**27t/ha**	**20t/ha**	
12	**10cm**	17t/ha	10t/ha	**Upright Bulbs**
13	**10cm**	17t/ha	10t/ha	**Inverted Bulbs**
14	**20cm**	17t/ha	10t/ha	**Upright Bulbs**
15	**20cm**	17t/ha	10t/ha	**Inverted Bulbs**
16	15cm	17t/ha	10t/ha	**Cover with polythene from planting until end November**
17	15cm	17t/ha	10t/ha	**Cover with fleece from start December until emergence**
18	15cm	17t/ha	10t/ha	**Ambient storage 1 day after HWT**
19	15cm	17t/ha	10t/ha	**Ambient storage 7 days after HWT**
20	15cm	17t/ha	10t/ha	**Ambient storage 28 days after HWT**
21	15cm	17t/ha	10t/ha	**35 Celsius storage 1 day after HWT**
22	15cm	17t/ha	10t/ha	**35 Celsius storage 7 days after HWT**
23	15cm	17t/ha	10t/ha	**35 Celsius storage 28 days after HWT**
E				**Reserve plot. Planted as control or extra treatments if not needed.**
24	15cm	17t/ha	10t/ha	**Irrigated - Add water to bring up to 83mm/month as neeeded in Summer**
25	15cm	17t/ha	10t/ha	**Fertiliser Placed 100% of broadcast rate**
26	15cm	17t/ha	10t/ha	**Fertiliser Placed 75%**
27	15cm	17t/ha	10t/ha	**Fertiliser Placed 50%**
28	15cm	17t/ha	10t/ha	**Fertiliser Placed 25%**
29	15cm	17t/ha	10t/ha	**No fertiliser**
30	15cm	17t/ha	10t/ha	**Fertiliser Placed 100% in contact with bulbs**

© Agriculture and Horticulture Development Board 2015. All rights reserved