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Project leader:	Dr. Tim Lacey, Vegetable Consultancy Services (Developments) Ltd.
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Location of project:	Review project
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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.

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GROWER SUMMARY

Headline

This project identifies the best approaches for supplying UK carrots through the winter/spring period.

Background

Current UK industry practice is to field-store carrots in-situ under polyethene and straw for winter/spring marketing. However, this practice is under increasing threat from rising straw, plastic and land-rent prices and it also poses agronomic issues for long-term sustainable production. Despite these threats, there are no currently proven alternative winter storage solutions that satisfy the requirements of the UK market: providing produce with suitable skin finish and taste, with low levels of disease at an economically viable cost.

Therefore, this project aimed to identify and review both currently established and novel strategies or technologies for providing a reliable supply of quality carrots during the winter/spring/early summer. Each option was briefly evaluated for its suitability to the UK industry (compared to the current practice) including estimated costs. Those techniques or strategies with the greatest potential for the UK industry were identified for future targeted research through the HDC.

Summary of the project and main conclusions

A combined approach was the best option for supplying UK carrots through the winer/spring period:

- Open ground with frost-tolerant varieties (+/- soil covering) for early supplies
- Polyethene + straw for mid-winter to late spring
- Refrigerated storage systems have potential, but require further adaptation / optimisation for the UK

Systems and techniques for supplying carrots in the “off-season” both from the UK and worldwide were collated and evaluated. Each method was summarised in a one-page data-sheet giving agronomic practices, harvesting techniques, storage method (if used), estimated costings through the supply period, a summary of pros and cons and an overall assessment of the suitability of the strategy/technique for the UK market.

A full interpretation of the data collated in this study can be gained from the data-sheet series in the science section of the report. A summary of the results is provided below:

- There may be opportunities for greater use of open-ground or ridged soil storage, making use of some of the newer, more frost-tolerant varieties for supplies in the early/mid period (realistically only to January without significant risk).

- Field storage under straw (no polyethene) can be used for early winter supplies, but suffers from many of the drawbacks of standard polyethene and straw and can reduce flexibility in supply chain. Consequently, its use is likely to remain limited.

- The standard method of field storage under polyethene and straw (poly+straw) still appears to provide a reasonable (and familiar) solution to carrot supplies during the winter/spring, but retains its existing problems. Modifications of the system by re-baling straw may have some financial benefits if demand (and therefore price) for straw increases and supplies become limited. However, any economic benefits are currently quite marginal, other than helping to secure supplies.

- There appears to be no alternative insulating materials (either biodegradable loose materials or synthetic covers) available that provide suitable properties at an acceptable price. However, advances in manufacturing technology and bulk purchasing may alter the economics in future.

- Imported carrots during the off-season are currently a necessity in the majority of years when UK crop does not quite provide sufficient supplies of quality produce in the overlap between stored carrots and fresh poly carrots. However, imported produce is typically expensive, subject to volatile market prices and unlikely to provide a welcome alternative to UK supplies through a longer period.

- Refrigerated storage of dirty carrots in boxes (as practiced in N Europe) is generally a more expensive option than field storage under straw, although it may match price towards the end of the season (subject to quality at out-turn). Its use in the UK will be limited by the availability of silty soils for growing crop with minimal skin abrasion, by the logistics of harvesting all winter crop during October/November and by the risk of entire store degradation.

- An alternative might be to modify the method, by pre-grading rejects in the field and employing state-of-the-art environmental control systems. This may bring some of the cost issues of box storage down to more realistic levels, but does not solve the shortfall in suitable soil types or other issues.

- The current practices of storing carrots washed and graded, either in bulk or in some form of perforated or basic modified atmosphere plastic bag do not appear to provide a solution to the UK issue.

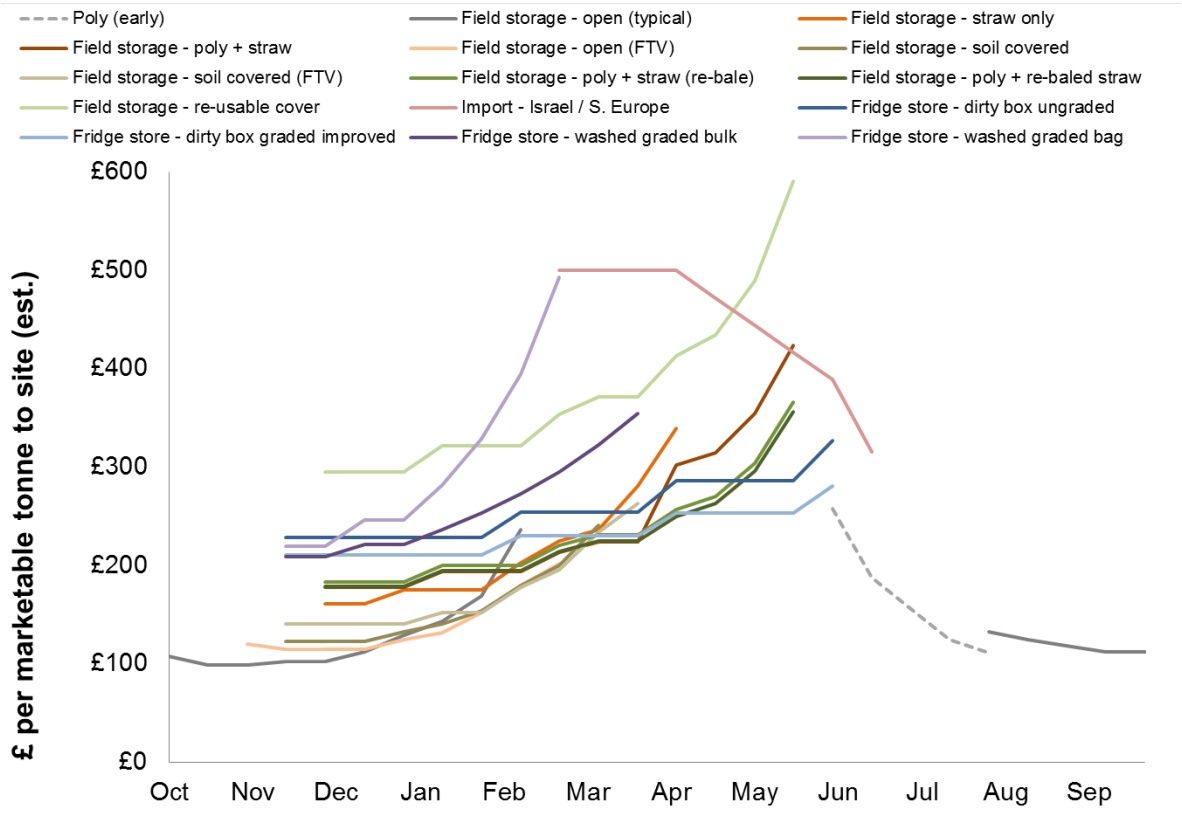
- There are a number of developments in refrigerated carrot storage which may provide sufficient improvement in disease control and crop quality to allow refrigerated storage to compete better with poly+straw methods. Most of these technologies are not yet commercially tested on carrots:

    - Steam sterilisation of washed carrots using intelligent control system to reduce storage diseases
    - Hydrogen peroxide fogging to reduce storage diseases
    - Ethylene scrubbing (carrots are very sensitive to ethylene, either from other crops or from propane-powered forklift exhausts)
    - UVC sterilisation of washed carrots to reduce storage diseases
    - Modified atmosphere packaging (either in bulk bins, or in smaller units) – techniques for fine-tuning the balance between crop and pathogen respiratory requirements are much more advanced than with previous films.
    - The principles of modified atmosphere packaging could be applied on a whole-store scale
    - Large advances in environmental control units, both in how units operate (e.g. continuously on variable-speed drive, rather than on-off and improved knowledge of air circulation), and in more accurate control of temperature and RH (e.g. improved “dry” fogging systems)

- Fungicide/chlorine rinses for washed produce may also help reduce disease issues (but regulatory and supermarket acceptance issues).

- It is suggested that these novel techniques are investigated in detail to determine their potential in developing refrigerated storage techniques suitable for the UK system.

Taking the available evidence to hand, it is suggested that drastic changes to current practice are not executed. However, it may be worth considering including some areas of alternative supply options within grower/packer supply chains to help manage costs and supplies through the winter/spring period. Examples include: open ground storage with frost tolerant varieties (in suitable location) for early winter supplies; straw, or more likely polyethene and straw for mid to late supplies (with or without some re-baling of used straw). Those with access to suitable soil types may wish to invest in dirty box stores, preferably with some pre-grading before store and the state-of-the-art environmental management systems, but this is only likely to provide a partial solution to winter/spring supplies. Lastly, work should continue to examine the potential of the emerging technologies to enhance existing storage techniques to be more suitable for the UK market in the future. A graphical summary of the estimated cost of each strategy / technique is given below.



Cost comparison between all “off-season” carrot supply strategies or techniques

Financial benefits

This project aimed only to collate and provide an information base around which further discussion on methods for supplying carrots in the winter/spring period could be centred. However, as an example, there are indications that modifying current storage practice by including a range of alternative options (such as open ground or soil covered storage using frost-tolerant varieties) could result in cost savings of around £64 per marketable tonne delivered to factory in December, dropping to around £14 in February (but with increased risk of crop loss attached). Further, in-depth costings would need to be carried out for specific strategies/techniques to accurately estimate potential financial benefits.

Action points for growers

Growers should actively consider their own off-season carrot supply strategies/techniques, paying particular attention to their specific circumstances (e.g. geography, soil base, varietal limitation, market requirement etc.).

It is suggested that the one-page data-sheets generated for in the full science report are used as a base-line for discussion and that further, in-depth investigations are carried out before changes are made to systems.

SCIENCE SECTION

Introduction

To provide reliable supplies of carrots with consistent quality through the winter and spring, the UK carrot industry currently relies on field storage *in-situ*. Typically, this consists of covering the crop with a layer of black polyethene, then a thick layer of straw to provide insulation from frost. This method has traditionally been considered to provide the best quality carrots for the lowest storage cost. However, there are increasing threats to the viability of this storage method:

- Straw is becoming less available and rapidly becoming more expensive (2010 price approximately 20-40% more than 2009 and 40-50% more than 2008).
- Plastic film cost is also increasing, in line with rising oil prices
- Land rent is increasing, particularly where the land is removed from two full rotations through long-term field-storage.
- Some sensory attributes (e.g. taste and sweetness) deteriorate under field-storage.
- Climate change predictions indicate that mild conditions that reduce crop quality and longevity through increased spoilage under field storage are likely to occur more frequently.
- There is a risk of increasing soil-borne disease loading where long-term field storage is practiced.
- Deer damage is increasingly becoming a problem for field-stored crop, with high levels of damage in some areas.
- Harvesting crop from the field during winter months can be logistically difficult, particularly during wet periods and under heavy snows, resulting in difficulty meeting market demands at realistic prices.
- Harvesting in poor conditions can cause significant damage to soil structure.
- The straw used for insulation (typically chopped and spread on the same field) reduces nitrogen availability for the following crop as it is degraded.

Internationally, few of the carrot industries that target markets similar to the UK use the straw-covered field-storage method favoured here. Instead, a range of techniques for year-round market supply are used. For example, some larger countries or those with suitable geography (e.g. USA, France, Spain, Italy) tend not to store carrots for any significant period, rather they rely on transporting fresh crop from regions with differing climate across

an accessible latitudinal (and/or altitudinal) range. Other countries, particularly at more northern latitudes (e.g Sweden, Finland, Holland, Germany, Canada) tend to grow carrots on heavier soils, storing the harvested crop with field soil in refrigerated box-stores.

Until recently, the availability of relatively cheap straw, the comparatively isolated geographic position and the oceanic climate of the British Isles have heavily favoured field-storage under straw in the UK, largely to the exclusion of other off-season carrot supply strategies. Nevertheless, as a result of the increasing economic and agronomic pressures on current practice, many carrot growers/packers are considering alternative options. However, because of the unique geography and climate of the UK and the piecemeal nature of most investigations to date, identifying and implementing suitable alternative strategies or techniques is proving to be difficult or impossible to achieve.

There is therefore a considerable requirement for a coherent review of both currently established and novel carrot supply strategies and techniques. This study aims to fulfill those needs by identifying and evaluating those options with the greatest potential to be targeted for future industry research and development. It is hoped that such an approach will ultimately lead to the establishment of a reliable off-season storage/supply strategy that maintains product quality whilst maximising the UK market opportunities.

Materials and methods

This project took the form of a desk-based research study, focusing primarily on sourcing data and information from key members of the UK and international carrot industries regarding the current and potential strategies in place to provide carrot supplies in the “off-season”. Further information has been obtained from individuals and companies associated with the carrot industry both in the UK and abroad as well as detailed literature searches.

The information gained from this process has been investigated, validated (as far as possible) and used to create a series of one-page data-sheets for each of the key carrot supply strategies/techniques identified. These data-sheets include information relating to the agronomic practices, harvesting techniques, storage method (if used), estimated costings through the supply period, a summary of pros and cons and an overall assessment of the suitability of the strategy/technique for the UK market.

Please note that costings in this report were based on typical production figures and prices received during the study and/or were calculated from similar industry figures. Some of these data varied considerably between sources for the same operation. In such cases, averages or best estimates have been used. For example, "marketable" crop in this study has been assumed to be all saleable roots of 25-40mm crown diameter – yet some packers have wider or tighter specifications that this. Similarly, the estimate of transport cost to packing site used in costings can vary significantly depending on packer location and grower field base, which may in turn depend on the time of year (e.g. southern or coastal areas for early carrots and northern or Scottish areas for late-season storage crops). Furthermore, due to the limited nature of this study, in-depth economic evaluations could not be carried out for each strategy/technique. Consequently, the costing information presented is intended as only a guideline to provide broad comparisons between methods. It is advised, therefore, that care should be taken in the interpretation of economic data from this report.

Please also note that due to the large volume of data generated, particularly from verbal communications, referencing specific information was not possible. A bibliography is provided in which information sources are detailed.

Results

The results from the desk study are presented as separate one-page data-sheets for each carrot supply strategy or technique on the following pages. The data used to generate the costings used on these data sheets is provided in Appendix 1 and 2.

A short summary of the collated information is provided in the Discussion section.

1 FIELD STORAGE - Open ground (typical)

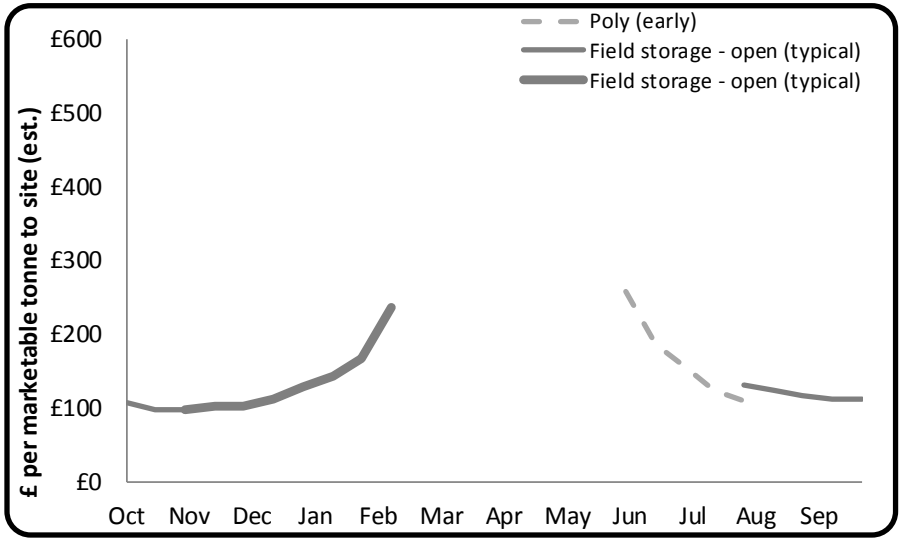
- **Used in the UK for supply period prior to heavy frosts - typically to November/December. Can be used for later storage crop, but at high risk of losses due to frost damage, regrowth, disease and/or inability to access the ground to harvest.**
- Typically drilled as 4x triple lines per bed on 1.83m to 2.03m wheel centres in April/May/June at densities of around 1.5-2.1 million seeds/ha, using standard Nantes varieties such as Nairobi/Nerac (Elsoms).
- Predominantly grown on sand and sandy loam soils (destoning typically required), but some production on silts and organic soils.
- Production areas typically Suffolk, Norfolk, Cambridgeshire, Nottinghamshire, Yorkshire, Lancashire, Perthshire and Aberdeenshire
- Crop harvested as required using top-lifter early in the autumn until the crops mature and foliage attachment becomes too weak . Share-lifter used after this point.
- Note that some varieties have stronger foliage attachment than others and suit top-lifting for a longer period.

Estimated costings

- Growing cost (seed, fertiliser, plant protection, water, rent, operations, overheads etc) = £5360/ha (+ transport to site)
- Marketable tonnage assumed to be 60t/ha in Nov, falling to 30t/ha by mid Feb
- Although potentially a cheap option for supply through to February, using open ground storage is very high risk due to frost damage / harvest inaccessibility.

Standard row configuration

Typical frost damage



Pros	Cons
• Little or no additional cost over growing costs • Good visual appearance of product • Spreads harvest workload through the year	• High risk strategy for supply beyond Nov/Dec (frost/regrowth/disease) • Poor weather affects harvest • Damage to soil structure if wet when harvesting • Can increase soil disease load • Subject to wildlife damage

Overall potential for UK winter/spring carrot supply : (0 = completely unsuitable, 10 = very high potential)	2

2 FIELD STORAGE - Open ground (frost tolerant varieties)

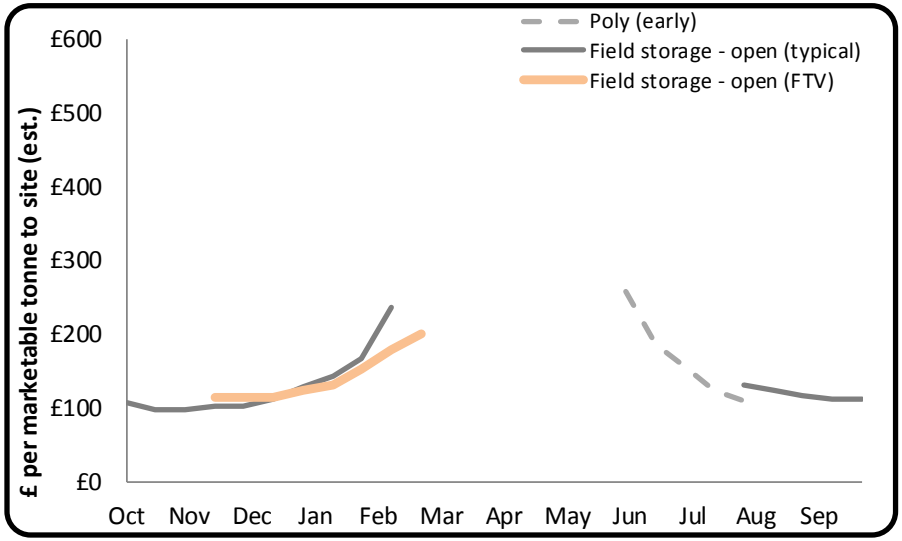
- **Some moderately frost tolerant varieties are currently grown in the UK and N Europe/Scandinavia which can extend the open-ground storage period over currently favoured varieties - typically to January/February. However, such crops are still susceptible to regrowth and disease risks.**
- Typically drilled as with standard maincrop (4x triple lines per bed on 1.83m to 2.03m wheel centres in April/May/June). Densities need to be reduced due to current varietal limitations (1.5-2 million seeds/ha). Varieties with known/claimed frost tolerance include Eskimo (Nickerson-Zwaan) and Elegance (Nunhems).
- Predominantly grown on sand and sandy loam soils (destoning typically required), but not well suited to silts/organic soil.
- Production areas as with standard maincrop (Suffolk, Norfolk, Cambridgeshire, Nottinghamshire, Yorkshire, Lancashire, Perthshire and Aberdeenshire)
- Currently available varieties with some frost tolerance tend to be slower growing, generally with lower yields than the typical Nantes varieties .
- Crop typically harvested using share-lifter as required, although some of the varieties with known frost tolerance also have stronger foliage and so may be top-lifted for a longer period.
- Using open ground storage can improve the environmental profile of growers, as a result of reduced inputs required for storage.

Estimated costings

- Growing cost (seed, fertiliser, plant protection, water, rent, operations, overheads etc) = £5460/ha (+ transport to site)
- Marketable tonnage assumed to be 50t/ha in Nov, falling to 30t/ha by early March
- Although potentially a cheap option for supply through to Feb or even March, using open ground storage even with frost tolerant varieties is high risk .

Carrot top-lift harvester

Frost tolerant variety Eskimo



Pros	Cons
• Small additional cost • Longer potential supply from open ground crop due to less frost damage risk • Good visual appearance of product • Spreads harvest workload through the year • Good "Green" profile	• High risk strategy for supply beyond Jan (regrowth/disease) • If storing late, land rent increases • Poor weather affects harvest • Damage to soil structure if wet when harvesting • Can increase soil disease load • Less harvest flexibility in varieties • Subject to wildlife damage

Overall potential for UK winter/spring carrot supply : **(0 = completely unsuitable, 10 = very high potential)**	**4**

3 FIELD STORAGE - Soil covered

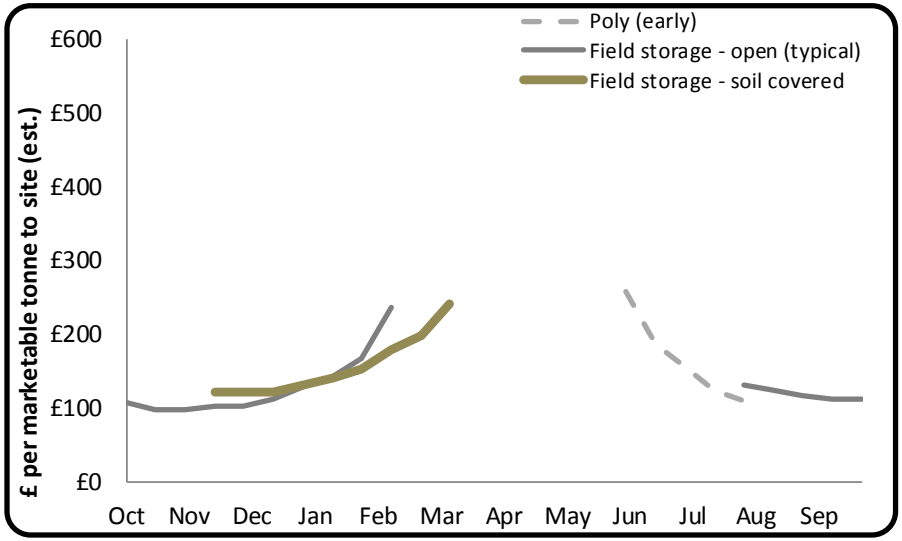
- **In parts of the UK and Europe (S France), limited areas of carrots are stored *in situ*, with soil ridged over the crop for protection. Storage typically to Jan/Feb.**
- Drilling configuration: typically 3x triple lines per bed on 1.83m wheel centres (or a 2+2 arrangement on 2.03m wheel centres) to allow room for soil to be ridged over crop. Drilled in May/June, with lower density (1.5-1.8 million seeds/ha) due to configuration using standard Nantes varieties such as Nairobi/Nerac (Elsoms).
- Restricted mainly to organic peat soils in Lancashire, and some sands/black sands in the South-East of England (destoning typically required). Organic soils tend to provide better insulation than mineral, but can prove difficult to travel at harvest. Best in soils with no stones (to avoid pulling stones from wheelings onto crop)
- Due to reduced population, yields are reduced where crop is grown specifically for soil ridging, but packout is better due to more uniform size (in 3-row systems).
- Prior to first major frosts (Oct-Dec), the crop is covered using discs or ridging bodies to drag soil from the wheelings and/or bed shoulder over the crop to a depth of 75-150mm. Typically provides frost protection to -5°C for several days (more on organic soils, less on mineral soils).
- Care must be taken to avoid exposing the roots near the edge of the bed and to avoid pulling stone from the wheelings onto the crop.
- Crop harvested using share-lifter as required.

Estimated costings

- Growing cost (seed, fertiliser, plant protection, water, rent, operations, overheads etc) = £5590/ha (+ transport to site)
- Additional cost of ridging soil over beds approx. £150/ha
- Total cost = £5740/ha (+ transport to site)
- Marketable tonnage assumed 52t/ha in Dec, falling to 26t/ha by mid March
- Although potentially a low-cost option for supply through to Feb or even March, soil covered storage suffers from low yields and still carries a significant risk of frost damage.

NO IMAGE

Carrot recently covered with soil



Pros	Cons
• Moderate cost • Moderate frost protection • Good visual appearance of product • Improved uniformity (in 3-row system) • Spreads harvest workload through the year • Moderate "Green" profile	• Risky storing beyond Feb • If storing late, land rent increases • Poor weather affects harvest • Damage to soil if wet at harvest • Can increase soil disease load • Crop must be grown specifically for ridging with soil • Reduced yield potential • Constraints on soil type • Subject to wildlife damage

Overall potential for UK winter/spring carrot supply : (0 = completely unsuitable, 10 = very high potential)	**4**

4 FIELD STORAGE - Soil covered (frost tolerant varieties)

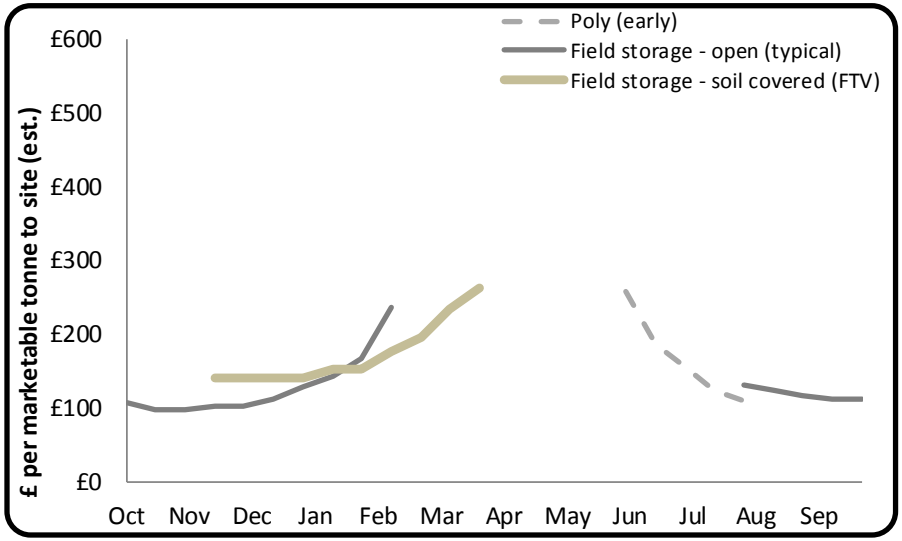
- **Combination of soil covered field storage, using frost tolerant varieties. It is thought that this technique is not currently practiced.**
- Drilling configuration as with soil covered (4) , but using varieties with know or claimed frost tolerance such as Eskimo (Nickerson-Zwaan) or Elegance (Nunhems).
- Soil types as with soil covered (4) - largely organic peats/black sands, but could be used on mineral soils. Geographic range could be extended slightly further into higher latitudes as a result of increased frost tolerance.
- Due to reduced population and varietal limitations, yields are likely to be further reduced from soil covered techniques with standard varieties.
- Prior to first major frosts (Oct-Dec), the crop is covered using discs or ridging bodies to drag soil from the wheelings and/or bed shoulder over the crop to a depth of 75-150mm. Typically provides frost protection to -5°C for several days (more on organic soils, less on mineral soils).
- Care must be taken to avoid exposing the roots near the edge of the bed and to avoid pulling stone from the wheelings onto the crop.
- Crop harvested using share-lifter as required.

Estimated costings

- Growing cost (seed, fertiliser, plant protection, water, rent, operations, overheads etc) = £5690/ha (+ transport to site)
- Additional cost of ridging soil over beds approx. £150/ha
- Total cost = £5840/ha (+ transport to site)
- Marketable tonnage assumed to be 46t/ha in Dec, falling to 24t/ha by late March
- Although the reduced risk of frost damage through to March has potential as a low-cost option, there is a significant yield penalty from row configuration and variety.

Carrot recently covered with soil

Frost tolerant variety Eskimo



Pros	Cons
• Moderate cost • Improved frost protection • Good visual appearance of product • Improved uniformity (in 3-row system) • Spreads harvest workload through the year • Moderate "Green" profile	• Risky storing beyond Feb/March • If storing late, land rent increases • Poor weather affects harvest • Damage to soil if wet at harvest • Can increase soil disease load • Crop must be grown specifically for ridging with soil • Reduced yield potential • Constraints on soil type • Subject to wildlife damage

Overall potential for UK winter/spring carrot supply : (0 = completely unsuitable, 10 = very high potential)	**5**

5 FIELD STORAGE - Straw covered (no polyethene)

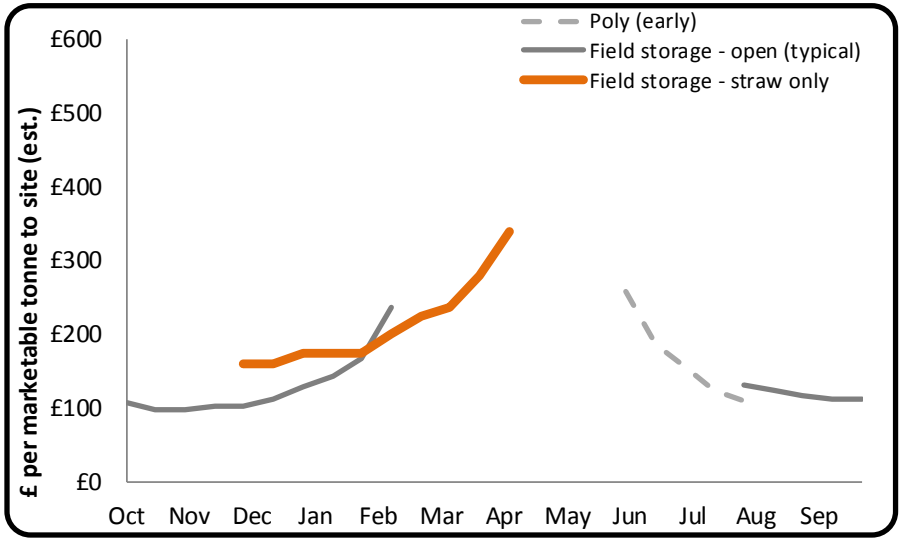
- **Used in the UK for supplying through to March/April, but high risk for long-term storage. More typically used with black polyethene beneath straw to prolong storability and increase harvest flexibility.**
- Carrots grown with same configuration and varieties as for standard maincrop, drilled May/June at densities of around 2-2.3 million seeds/ha.
- Predominantly sand and sandy loam soils (destoning typically required).
- Production areas typically Suffolk, Norfolk, Cambridgeshire, Nottinghamshire, Yorkshire, Lancashire, Perthshire and Aberdeenshire, with higher latitudes tending to provide the latest storage options (with polyethene option).
- Prior to first major frosts (typically Oct-Dec), the crop is covered with a thick layer of wheat straw, using specialist straw spreading equipment at a rate of approx. 100 bales per hectare. Where heavier frosts are expected, to prolong storage or protect from wildlife damage, black polyethene is laid first before covering with straw.
- When the crop is required for market, the straw is removed and deposited beside the bed .
- After harvesting (share lift), the remaining straw must be further chopped and worked to aid incorporation to the soil. This often limits the following cropping.

Estimated costings

- Growing cost (seed, fertiliser, plant protection, water, rent, operations, overheads etc) = £5760/ha (+ transport to site)
- Straw approximately £2300/ha, assuming 100 x £23 per large Hesston bale
- Additional operations (straw laying, removal, incorporation) = £800/ha
- Total cost £8860/ha (+ transport to site)
- For additional 10 bales/ha = + £250/ha
- If straw price @ £18/bale = £8360/ha; @£28/bale = £9360/ha
- Marketable tonnage assumed to be 60t/ha in Dec, falling to 28t/ha by April

Carrot strawing from the air

Strawed carrots



Pros	Cons
• Can be cheaper option for supply to Jan/Feb/March • Good visual appearance of product • Some protection of crop against wildlife damage • Spreads harvest workload through the year • Opportunity for high gross yield	• Supply to April at latest - (risky) • Rapidly increasing straw / rent • Rent increases with storage time • Poor weather affects harvest • Damage to soil if wet harvest • Increases soil disease load • Flavour decreases • Straw returned to soil can lock N • Limitation on following crop

Overall potential for UK winter/spring carrot supply :
(0 = completely unsuitable, 10 = very high potential) **5**

6 FIELD STORAGE - Black polyethene + straw covered

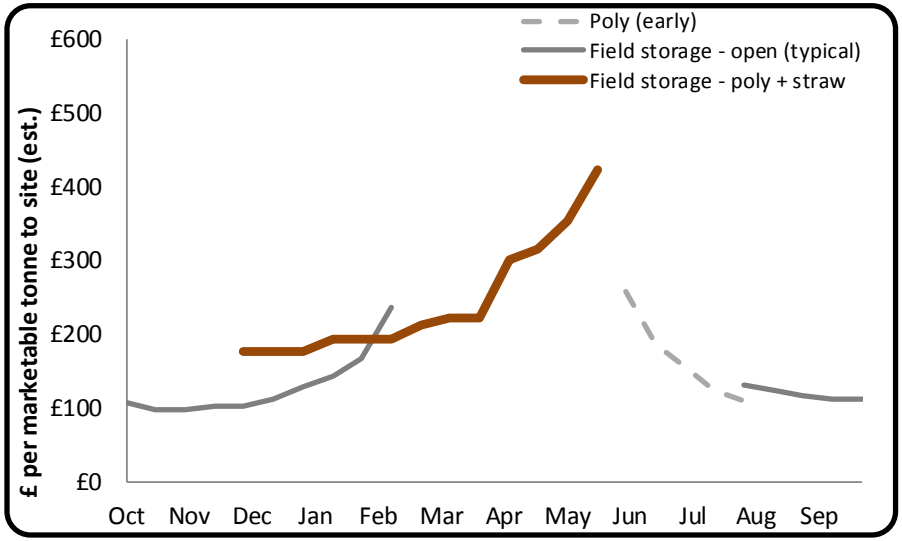
- **Typical system in UK for supplying to May/June. Some use in Scandinavia. Systems without poly can be used for earlier supply where frost risk lower.**
- Carrots grown with same configuration and varieties as for standard maincrop, drilled May/June at densities of around 2-2.3 million seeds/ha.
- Production areas typically Suffolk, Norfolk, Cambridgeshire, Nottinghamshire, Yorkshire, Lancashire, Perthshire and Aberdeenshire, with higher latitudes tending to provide the latest storage (largely due to slower re-growth in spring). NB for the majority of packers, late stored crop from Scotland incurs significantly increased transport costs.
- Prior to first major frosts (typically Oct-Dec), the crop is covered with black polyethene (40 micron), then a thick layer of wheat straw using specialist straw spreading equipment at a rate of 100-125 bales per hectare. The polyethene layer acts both as additional insulation and also to prevent light reaching the crop, reducing re-growth in the spring. Areas prone to heavier frosts (e.g. . Scotland) tend to use higher rates of straw.
- When the crop is required for market, the straw is removed from the polyethene and deposited beside the bed. The polyethene is removed using standard poly removal kit and transported either to landfill or for recycling.
- After harvesting (share lift), the remaining straw must be further chopped and worked to aid incorporation to the soil. This often limits the following cropping.

Estimated costing

- Growing cost (seed, fertiliser, plant protection, water, rent, operations, overheads etc) = £5850/ha (+ transport to site)
- NB transport significantly higher in April/May/June due to haulage from Scotland
- Straw and poly approximately £2790/ha, assuming 100 x £23 per large Hesston
- Additional operations (poly + straw laying, removal and incorporation/disposal) = £1240/ha
- Total cost £9880/ha (for additional 10 bales/ha, add approx. £250/ha)
- If straw @ £18/bale = £9380/ha; @£28/bale = £10380/ha
- Marketable tonnage assumed to be 60t/ha in Dec, falling to 30t/ha by May

Poly + straw laying

Poly + Straw removal



Pros	Cons
• Most economical current option for supply to May/June • Good visual appearance of product • Poly helps protect crop from wildlife damage • Spreads harvest workload through the year • Opportunity for high gross yield	• Rapidly increasing straw, poly and land rent cost • Rent increases with storage time • Poor weather affects harvest • Damage to soil if wet harvest • Increases soil disease load • Flavour decreases • Straw returned to soil can lock N • Limitation on following crop

Overall potential for UK winter/spring carrot supply : **7**
(0 = completely unsuitable, 10 = very high potential)

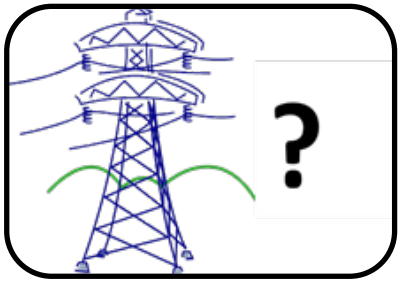
7 FIELD STORAGE - Poly + straw covered (straw re-baled for re-use/biomass fuel)

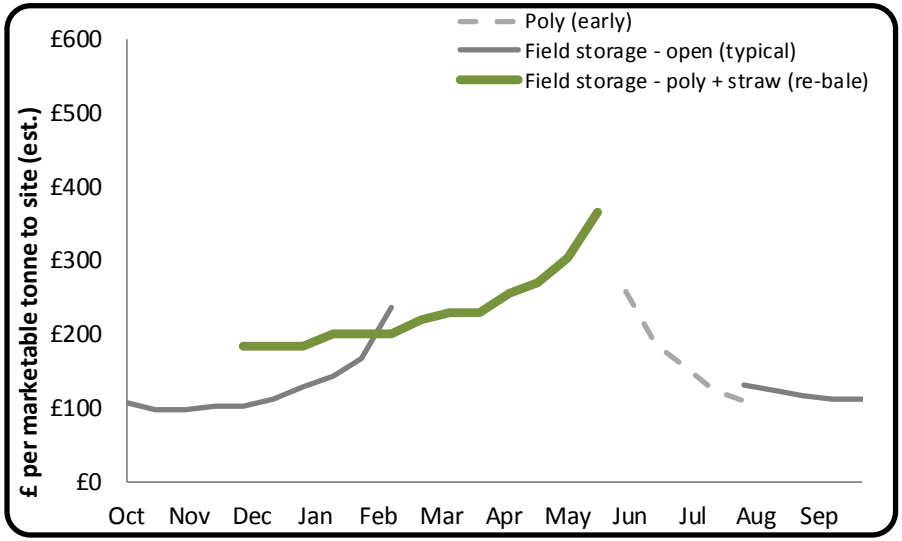
- **As with field storage under poly + straw, but re-baling used straw either for re-use in following season, or supply to biomass power station.**
- Production and storage method as with poly + straw, although without any straw chopping on removal from crop. After harvest complete, straw is windrowed to dry, then re-baled. Returns estimated at about 40% of original application due to losses.
- Re-baled straw can be re-used for strawing carrots in following year. However, due to the low quality, a higher rate will be required to achieve similar insulation properties.
- Alternatively, re-baled straw may find an outlet with biomass fuelled power stations. However, there is currently no precedent for this, and it is uncertain whether power stations would accept non-virgin crop due to soil/stone/plastic contamination issues and the inevitably variable nature of the product. Current virgin straw is contracted to biomass power stations at £35-42/tonne ex-farm (adjusted to 16% moisture content).
- After re-baling, a reduced number of cultivation passes are likely to be required to work remaining straw into the soil.

Estimated costings

- Growing cost (seed, fertiliser, plant protection, water, rent, operations, overheads etc) = £5850/ha (+ transport to site)
- Straw and poly approximately £2790/ha, assuming 100 x £23 per large Hesston
- Additional operations (poly+ straw laying, removal, disposal, windrowing, re-baling) = £1575/ha, assuming 40% return of bales/ha at cost of £26/bale.
- For re-use, it is assumed that re-baling cost is split 50:50 between current and next crop. For Biomass fuel = £13/bale or c£20/t (if accepted).
- Total cost £10215/ha (for additional 10 bales/ha, add approx. £250/ha)
- Marketable tonnage assumed to be 60t/ha in Dec, falling to 30t/ha by May

Poly+straw removal





Pros	Cons
• Similar to current poly+straw option for supply to May/June • Good visual appearance of product • Poly helps protect crop from wildlife damage • Spreads harvest workload • Moderate "Green" profile • Reduced N lock-up • Opportunity for high gross yield	• Rapidly increasing straw, poly and land rent cost • Rent increases with storage time • Poor weather affects harvest • Damage to soil structure if wet when harvesting • Increases soil disease load • Flavour decreases • Difficulty and time for re-baling • Weather may prevent re-baling

Overall potential for UK winter/spring carrot supply : (0 = completely unsuitable, 10 = very high potential)	7

8 FIELD STORAGE - Poly + re-baled straw covered

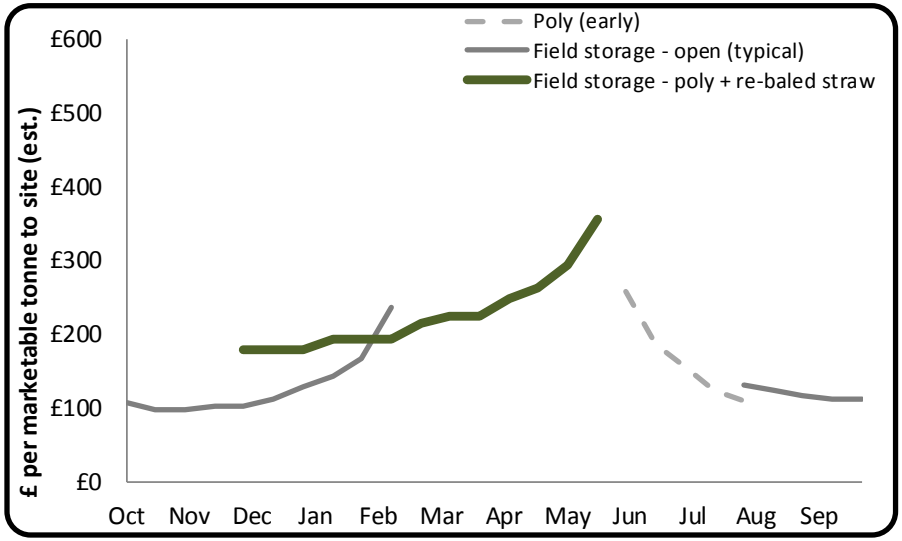
- **As with field storage under poly + straw (6), but using straw re-baled from previous year's strawed crop. Some growers are currently practicing this technique on part of their carrot storage area.**
- Production and storage method as with poly + straw (6), but with straw supplied from re-baled material from previous year. Note that, due to the lower quality, a higher rate (approx. 25% increase) of re-baled straw will be required to achieve similar insulation properties.
- It is acknowledged that re-using straw is not a self sustaining system: assuming a 25% higher application rate is required for re-baled straw, and that re-baling returns 40% of the original bales, then approximately 75% of total strawed area would have to be from virgin straw per annum.

Estimated costings

- Growing cost (seed, fertiliser, plant protection, water, rent, operations, overheads etc) = £5850/ha (+ transport to site)
- Straw and poly approximately £2715/ha, assuming 25% of are with re-baled @ 125 x £13 per large Hesston bale (i.e. 50% of production cost of bale, split between previous season and current season) + £3 per bale for transport to site. Remaining 75% at virgin straw cost.
- Additional operations (poly+ straw laying at higher cost, removal, poly disposal, straw chopping and incorporation) = £1360/ha
- Total cost £9700/ha (for additional 10 bales/ha, add approx. £270/ha)
- Marketable tonnage assumed to be 60t/ha in Dec, falling to 30t/ha by May

Poly + straw removal

Poly + straw laying



Pros	Cons
• Similar to current poly+straw option for supply to May/June • Good visual appearance of product • Poly helps protect crop from wildlife damage • Spreads harvest workload • Straw supply partially protected • Moderate "Green" profile • Opportunity for high gross yield	• Rapidly increasing straw, poly and land rent cost • Rent increases with storage time • Poor weather affects harvest • Damage to soil if wet harvest • Increases soil disease load • Flavour decreases • Difficulty and time for re-baling • Limitation on following crop • Weather may prevent re-baling

Overall potential for UK winter/spring carrot supply : (0 = completely unsuitable, 10 = very high potential)	7

9 FIELD STORAGE - Poly + alternative loose biodegradable insulating product

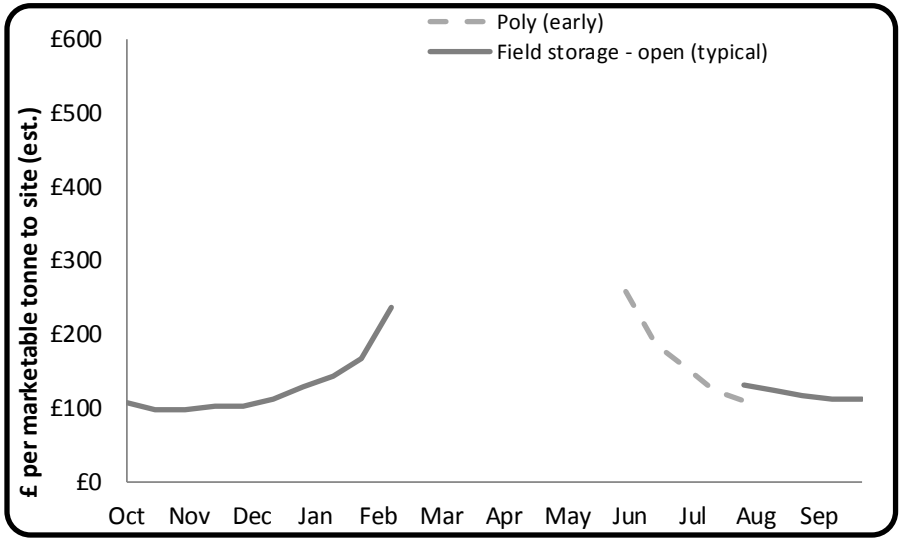
- **As with field storage under poly + straw , but using an alternative biodegradable loose insulating product instead of wheat straw.**
- Alternative biodegradable loose insulating products to straw were investigated, including shredded waste paper, wood ships/shavings, wool and alternative combinable crop straws.
- Waste paper, wood chips/shavings and wool would not prove suitable products due to limitations on some or all of: weight/bulk to insulation ratio; waste status; potential contamination issues (oils, resins, heavy metals); material handling; durability of insulation properties; cost; high N lock-up and slow biodegradation.
- Most alternative combinable crop straws (barley, oat, rye, rape, field bean, hemp) are also either unsuitable due to: poor straw structure/friability; difficulty in baling/handling; lower potential for insulation; difficulty sourcing and/or demands that create prices similar to wheat straw.
- Consequently, it is believed that there are no suitable alternative loose biodegradable insulating products available that could replace wheat straw.

Estimated costings

- N/a

Shredded waste paper

Wood shavings



Pros	Cons
• Alternative to wheat straw, with reduced cost for similar insulation properties?	• No suitable products available

Overall potential for UK winter/spring carrot supply : (0 = completely unsuitable, 10 = very high potential)	0

10 FIELD STORAGE - Re-usable synthetic cover

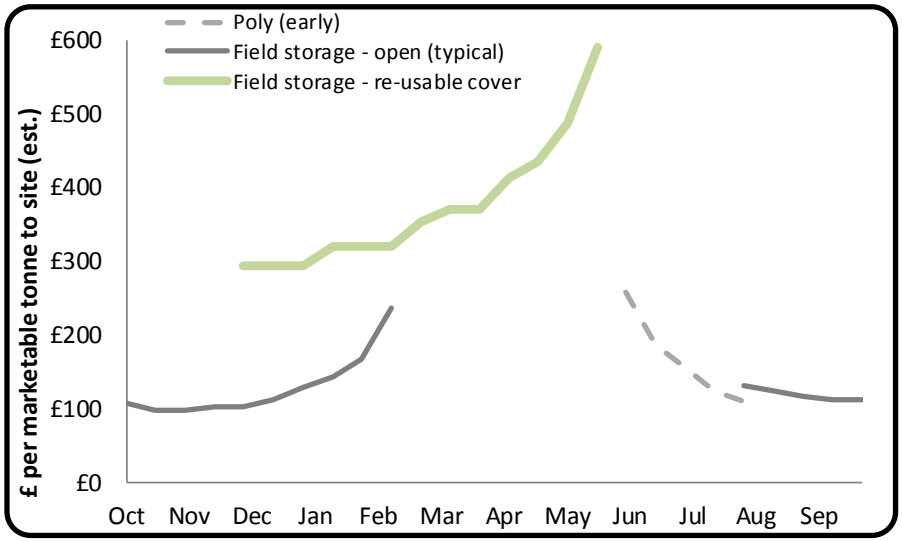
- **The use of field storage with a re-usable synthetic insulation cover instead of wheat straw has been investigated. This system is not currently in use.**
- Crop would be grown as for standard poly+straw field storage (similar varieties, soil types, geographical locations)
- Prior to first major frosts (typically Oct-Dec), the crop would be covered with a re-usable synthetic insulating and opaque material, which would be left on the crop until harvest was required as with straw-based systems. At harvest, the covers would be removed and transported for storage prior to re-use the following year.
- Currently there are no materials suitable for large-scale field use. However, there are a number of thin (20-40mm) flexible, multi-layer foil/fabric + insulation products that could be modified with a suitably robust outer layer for multi-season use. Examples include the small-scale horticultural product, Trident Potato Fleece or construction products (e.g. Tri-Iso 10 or Superquilt). Manufacturers contacted for this project would not speculate on feasibility or cost.
- Insulation values difficult to find for loose straw, but Potato Fleece claims to be equivalent to 45cm straw and construction products generally are higher rating.
- New systems for laying/removing covers would be required (NB typically 0.5kg/m2 when dry, more when used), and storage area(s) would have to be identified.
- Potential issues include a potentially poor environmental profile, disease transfer risk, bulky and heavy product (especially when wet and dirty), storage, disposal.

Estimated costings

- Growing cost (seed, fertiliser, plant protection, water, rent, operations, overheads etc) = £5850/ha (+ transport to site)
- Cover price based on existing materials: Retail @ c£8-10/m2, but although agricultural product much more robust, it would be on much larger scale, so assume £5/m2, with 5 year lifespan = £10000/ha
- Additional operations (transport to site, laying, removal , transport to storage, storage costs) = £1040/ha
- Total cost £16890/ha (+transport to site)
- Marketable tonnage assumed to be 60t/ha in Dec, falling to 30t/ha by May

Trident Potato Fleece

Superquilt / Tri-Iso 10



Pros	Cons
• No reliance on straw, but equal or better insulation • No N lock-up • Good visual appearance of product • Cover helps protect crop from wildlife damage . • Spreads harvest workload through the year • Opportunity for high gross yield	• Expensive (and likely to increase) • Still have rent costs • Poor weather affects harvest • Damage to soil if wet harvest • Increases soil disease load • Risk of disease transfer on covers • Transport/storage issues • Flavour decreases • Poor "Green " profile

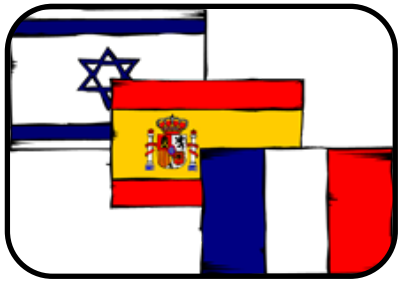
Overall potential for UK winter/spring carrot supply : (0 = completely unsuitable, 10 = very high potential)	**3**

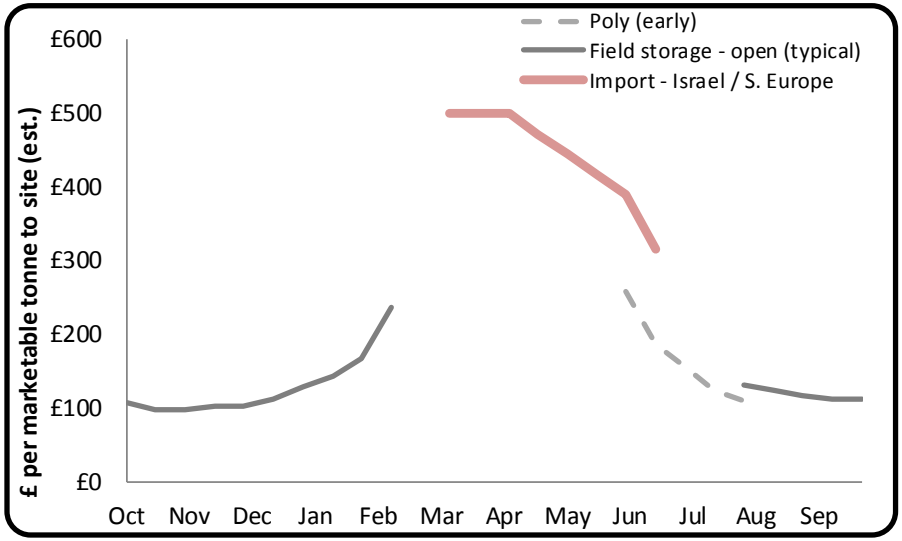
11 IMPORT - Israel / Spain / S. France / W or S Africa / Australia / NZ / China

- **Imports are commonly used to bridge the current supply gap in the UK (usually May/Early June, but sometimes for longer periods, depending on season).**
- Typically, imports during the current supply gap come from Israel (relatively stable supply from March to June, fixed prices, good quality, but approx. 2 week lead time required), south Spain (more volatile supply and prices, usually April to June, but only 3-5 day lead time) or south France (relatively stable supply, but volatile prices, mid-May to June, only 2-4 day lead time). Prices (particularly Spain/France) vary according to demand from UK, Northern Europe, Eastern Europe and Russia and are subject to fluctuations in exchange rate. Crop is usually delivered to packers washed and graded (sometimes in modified atmosphere packaging to stabilise product during short-term storage and transit), requiring only a final re-grade/pack at c90% packout.
- Historically, carrots have been imported to the UK from South Africa, Australia and New Zealand during the winter/spring period. However, these imports have largely ceased due to increased efficiencies in the UK off-season supply chain and increased shipping costs for imports.
- Recently, carrots have become available from China in the UK at prices similar to European/Israeli imports (c£500/tonne to site c90% packable). It is expected that imports from African/Southern Hemisphere areas would be similarly priced and therefore only viable in times of particular shortage.

Estimated costings

- For period from March to June, it is assumed that imports would be available from Israel/Spain/France for an average price of £400/t delivered to site , ranging from £450 in the earlier and mid period to £300 by late June.
- It is assumed that all produce is washed and graded in some form of bulk packaging that requires final grading and re-packing @ c90% packout.
- Note that prices for imports are subject to supply/demand and could vary considerably.





Pros	Cons
• Provides buffer supply during problematic April/May/early June period • Fresh crop with good taste • Allows down-time for repairs to harvesting equipment/factory • No carrot-fly damage ?	• Usually expensive • Subject to market demand from wide geographical area • Subject to exchange rate • Prices can fluctuate significantly (particularly market traders) • Skin finish can be poorer than UK crop (if available) • Relatively poor "Green" profile

Overall potential for UK winter/spring carrot supply : (0 = completely unsuitable, 10 = very high potential)	6

12 FRIDGE STORE - (dirty crop, ungraded, boxes)

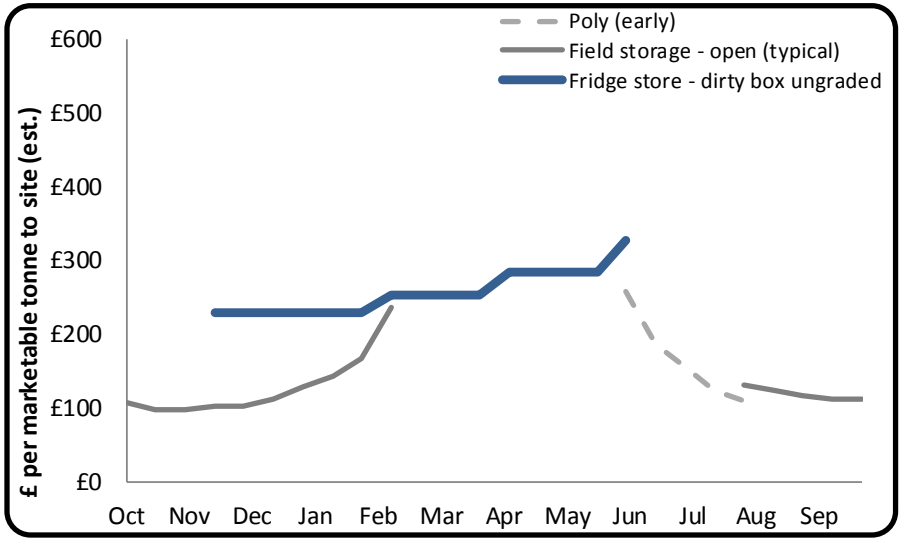
- **The standard carrot storage method in most of northern Europe on silty/clay soils, particularly where winters are harsher. Unwashed crop is stored in boxes under refrigeration at high humidity until June. Used across Holland, Belgium, Germany, Scandinavia. Variations in USA, Canada. Limited use in UK at present.**
- Crop is drilled in May as a single row (twin/triple line or scatter band) on ridges at 75cm spacing to aid top-lifting (some countries use beds - e.g. Finland, UK).
- Densities are around 1.6-2.0 million seeds/ha using Nantes varieties with strong tops, such as Nerac (Elsoms), Maestro (Nickerson-Zwaan) or Elegance (Nunhems).
- Typically silt/silt-loam soils to minimise abrasive skin damage. Destoning is not usually required on these soils. Crop from sandier soils tends to store only to Feb.
- Crop is harvested by top-lifter (or share lifter in some cases) directly into wooden tonne boxes (with 20-30% soil) at physiological maturity, but before senescence (usually Oct). Timing is believed to be critical to storage success. Harvesting is targeted at soil temperatures of <10°C to minimise crop heat. Typically 120-140t/ha.
- Crop is stored in refrigerated box store, usually with passive ventilation and some form of environmental control to bring temperatures down by about 1.5°C per week to 0.5-1.0°C and RH of 75-90%. Some stores manage CO_2 to reduce spoilage by flushing with fresh air. Packouts (for European market) typically 50-70%.
- Good practice is to hot-box samples on store entry and during storage to inform outloading requirements and monitor potentially catastrophic disease outbreaks.

Estimated costings

- Growing cost (seed, fertiliser, plant protection, water, rent, operations, overheads etc) = £5900/ha (+ transport to site). It is assumed that harvesting capacity/cost will have to be doubled to account for high peak demand to store.
- Store capital costs are assumed to be approx. £300/t stored (off-set over 10 years) + £70 per tonne box (off-set over 5 years) for 120 t/ha.
- Store variable costs are assumed to be approx. £15/t electricity /management.
- Marketable tonnage out of store assumed to be 60t/ha in Nov, falling to 42t/ha by June (adjusted from Dutch 60-70% packout to 35-50% for UK)
- Note that stores can fail (due to crop and/or mechanical/control issues)

Ridge drilling (Holland)

Top-lifting into boxes



Pros	Cons
• Potential to store to June • No additional rent/field storage costs • No N lock-up • Better product flavour/sweetness • Easier to meet fluctuating demands • Cooling/humidification designs improving (e.g. JD Cooling/Klim'top). • Alternative varieties to extend soils range? • No carrot-fly damage through winter	• Capital expense - store/machinery • Suitable land resource very limited • Risk of store/crop failure - disease • Skin finish poorer • Yields reduced by ridge/variety • High pressure to harvest in Oct • Wasteful to store reject crop/soil • Disposal of soil an issue • High fungicide input for toplifting • Poor "Green" profile

Overall potential for UK winter/spring carrot supply :
(0 = completely unsuitable, 10 = very high potential) **5**

13 FRIDGE STORE - (dirty crop, graded into boxes, improved store climate)

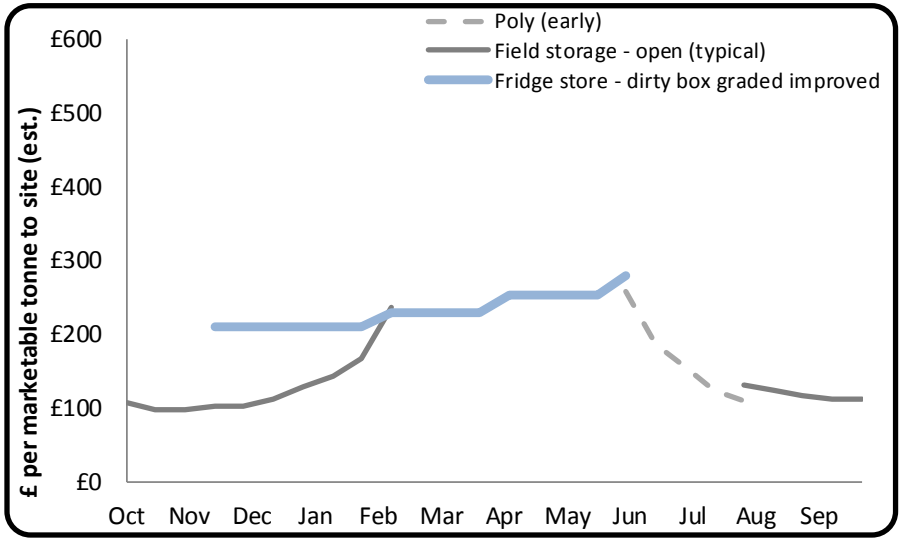
- **Suggested improvement to standard box storage method by pre-grading crop into boxes on harvester, then state-of-the-art climate control technology in store.**
- It is assumed that crop would be produced in the same manner as for standard fridge box storage, (soil type, variety, density, configuration etc).
- Harvest process would also be the same, but using harvesters with picking tables to pre-grade all crop going into store, removing the worst defects in the field (estimated 10t/ha removed in field = 110-130t/ha)
- Crop is stored in refrigerated box store, with state-of-the-art refrigeration, airflow and humidification control targeting similar parameters to standard box store. Example systems include the Passive Up-Flow (PUF) system from JD Cooling, Tru-Fog from Pendred and environmental control systems from Klim'Top Controls which can offer improved temperature, humidity and CO2 management and reduced energy costs.
- By reducing waste tonnage transported and stored, and improving store quality, costs per tonne of marketable product could be significantly reduced over standard fridge stores.
- Some growers use basic modified atmosphere plastic liners (often just perforated plastic) to help maintain crop condition.

Estimated costings

- Growing cost (seed, fertiliser, plant protection, water, rent, operations, overheads etc) = £6300/ha (+ transport to site). Additional cost over standard box store for machinery modification and labour to field-grade.
- Store capital costs are assumed to be higher at approx. £350/t stored (off-set over 10 years) + £70 per tonne box (off-set over 5 years) for 110t/ha
- Store variable costs are assumed to be approx. £14/t electricity /management.
- Marketable tonnage out of store assumed to be 66t/ha in Nov, falling to 50t/ha by June (assuming 10% increase in packout over standard method)
- Note that stores can fail (due to crop and/or mechanical/control issues)

Top-lifting into boxes

State-of-the-art carrot box store



Pros	Cons
• Potential to store to June • No additional rent/field storage costs • No N lock-up • Better product flavour/sweetness • Easier to meet fluctuating demands • Lower waste crop into store • Improved energy use • Further improvements possible - e.g. modified atmosphere etc. • No carrot-fly damage through winter	• Capital expense - store/machinery • Suitable land resource very limited • Risk of store/crop failure - disease • Skin finish poorer • Yields reduced by ridge/variety • High pressure to harvest in Oct • Wasteful to store reject crop/soil • Disposal of soil an issue • High fungicide input for toplifting • Poor "Green" profile

Overall potential for UK winter/spring carrot supply : (0 = completely unsuitable, 10 = very high potential)	6

14 FRIDGE STORE - (washed, graded crop placed into bulk store)

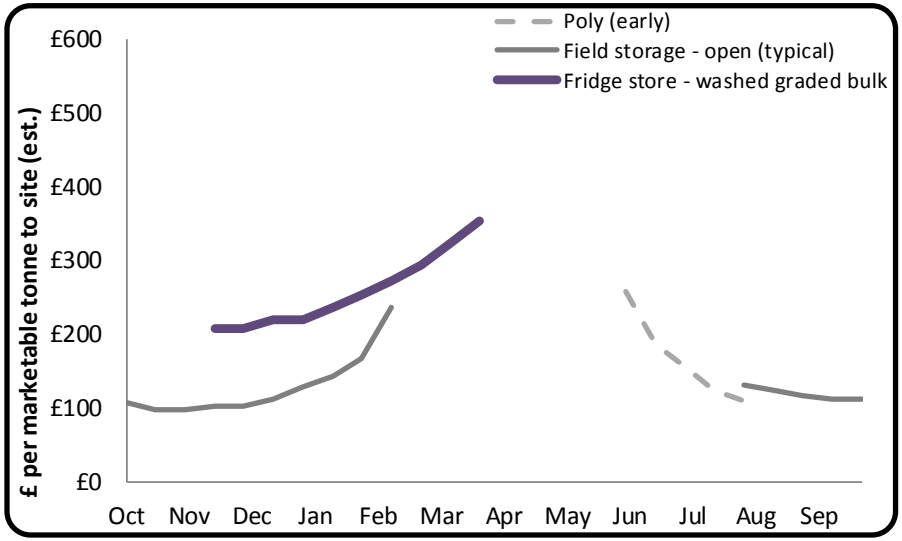
- **Some growers in the USA and Canada store carrots washed and graded in bulk stores, with removal either by bucket or water flume. Storage period can be relatively short (typically Feb/March), but up to 7 months for high dry matter varieties, and skin quality is typically poor.**
- Crop is produced in a similar manner as for standard fridge box storage, (soil type, variety, density, configuration etc) - designed to cause minimal skin damage.
- Varieties tend to include Nantes, Danvers and Imperator types, usually targeting higher dry matter types for better storage (limited Nantes options?)
- Harvest is typically by top-lifter in October/November (at crop maturity) into bulk trailers, then removed to washer/store area.
- On receipt, crop is hydrocooled as soon as possible to remove field heat, then washed (in 100ppm chlorinated water at pH 6.5-7.5) ,graded to remove defects and diseased roots and usually rinsed/sprayed with clean fungicide-treated water (e.g. chlorine in USA or fludioxonil approved in Canada) before loading into sterilised bulk stores.
- Stores typically follow conventional bulk-storage designs with under-floor ventilation blowing moderate volumes of cold air through the crop to remove respiration heat. Target -0.5-1.0°C and 98-100% RH, but avoiding moisture condensing on crop surface. Some stores use flumes to unload to packing area with minimal damage
- On out-loading, crop generally require re-washing, grading and polishing to return skin finish/remove storage rots etc.

Estimated costings

- Growing cost (seed, fertiliser, plant protection, water, rent, operations, overheads etc) = £5900/ha (+ transport to site). Assumed similar to dirty box-store. Yield assumed similar at 120t/ha (dirty, inc. c25% soil)
- Bulk store and washer capital costs are estimated at approx. £500/t stored (off-set over 10 years) . Assumed that 60% of harvested crop is stored after grading.
- Variable costs assumed to be approx. £20/t electricity /labour.
- Marketable tonnage out of store assumed to be 85% pack-out of input stock (=61t/ha) in Nov, falling to 50% (36t/ha) by mid April
- Note that stores can fail (due to crop and/or mechanical/control issues)

Top-lifting into boxes

Hydrocooling carrots



Pros	Cons
• Potential to store to April • No additional rent/field storage costs • No N lock-up • Better product flavour/sweetness • Easier to meet fluctuating demands • Lower waste crop into store • Improved energy use • Further improvements possible - e.g. modified atmosphere etc. • No carrot-fly damage through winter	• Increased capital expense - store/machinery • Suitable land resource very limited • Risk of store/crop failure - disease • Skin finish poor • Yields reduced by ridge/variety • Higher pressure to harvest and wash /grade in Oct/Nov • High fungicide input for toplifting • Poor "Green" profile

Overall potential for UK winter/spring carrot supply : (0 = completely unsuitable, 10 = very high potential)	**4**

15 FRIDGE STORE - (washed, graded crop packed in bags)

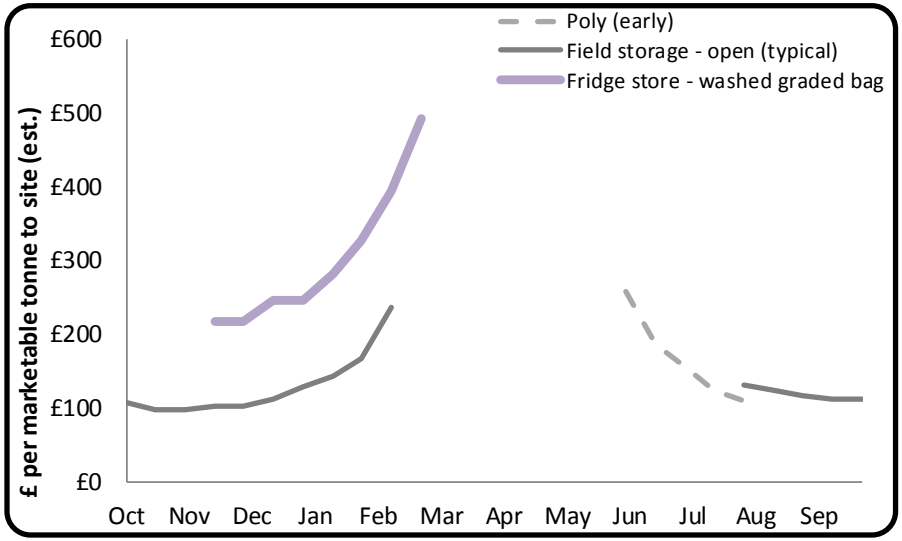
- **Carrots washed, graded and packed in plastic bags (usually either perforated, or some form of basic modified atmosphere packaging) then stored in fridge store. Commonly used for short-term storage/export (4-6wk) in Israel, Australia, China. Some growers in the USA use a similar system for longer storage, but skin quality is typically poor.**
- Crop production varies, but is assumed that a similar manner as for standard fridge box storage, would be required to minimise skin damage.
- Varieties vary, but tend to include Nantes, Danvers and Imperator types, usually targeting higher dry matter types for better storage (limited Nantes options?)
- Harvest, hydrocooling and grading are similar to bulk storage of washed carrots, with crop then being placed into varying sizes of perforated or basic modified atmosphere bags (either as product ready for customer in the case of shorter-term storage, or in larger volumes to suit re-washing/polishing/grading for longer storage). Crop is then stored under similar environmental conditions to bulk washed product (-0.5-1.0°C, 98-100%RH).
- The use of modified atmosphere packaging for this purpose is relatively basic at present . However, significant research has been carried out to identify the optimum film type and hole configuration to prolong crop storage and minimise spoilage (e.g. Institute of Food Research, Norwich).

Estimated costings

- Growing cost (seed, fertiliser, plant protection, water, rent, operations, overheads etc) = £5900/ha (+ transport to site). Assumed similar to dirty box-store. Yield assumed similar at 120t/ha (dirty, inc. c25% soil)
- Fridge store and washer capital costs are estimated at approx. £600/t stored (off-set over 10 years) . Assumed that 60% of harvested crop is stored after grading.
- Variable costs assumed to be approx. £30/t electricity /labour/packaging
- Marketable tonnage out of store assumed to be 90% pack-out of input stock (=65t/ha) in Nov, falling rapidly to 40% (30t/ha) by end Feb
- Note that stores can fail (due to crop and/or mechanical/control issues)

Top-lifting into boxes

Hydrocooling carrots



Pros	Cons
• No additional rent/field storage costs • No N lock-up • Better product flavour/sweetness • Easier to meet fluctuating demands • Lower waste crop into store • Improved energy use • Further improvements possible - e.g. improved, targeted modified atmosphere, ethylene scrubbing etc. • No carrot-fly damage through winter	• Increased capital expense - store/machinery/packaging • Suitable land resource very limited • Risk of store/crop failure - disease • Skin finish poor • Yields reduced by ridge/variety • Higher pressure to harvest and wash /grade in Oct/Nov • High fungicide input for toplifting • Poor "Green" profile

Overall potential for UK winter/spring carrot supply : (0 = completely unsuitable, 10 = very high potential)	**3**

Discussion

Summary graphs comparing all field storage methods together and all refrigerated store methods together are presented in Figure 1 and Figure 2 respectively.

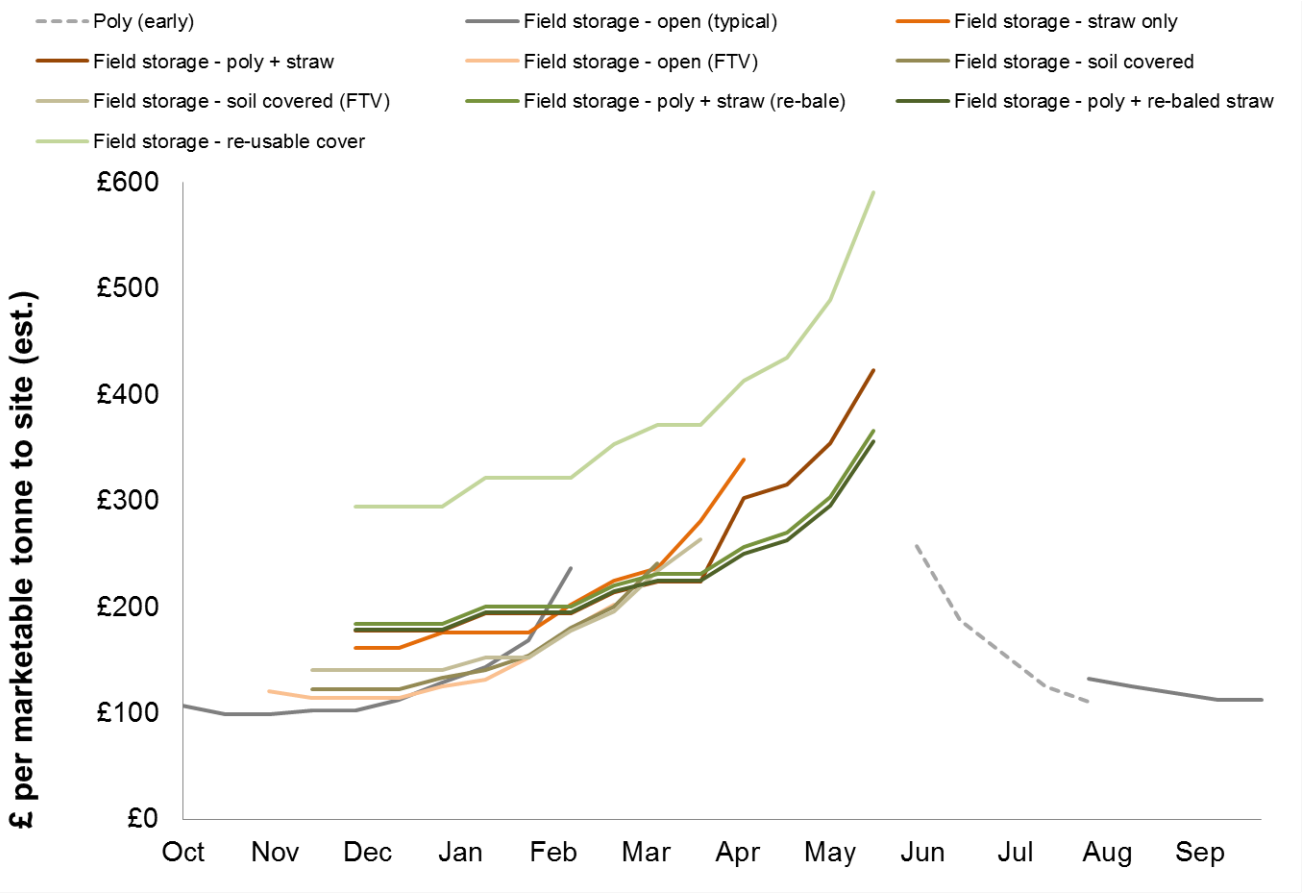


Figure 1 Cost comparison of all field storage methods for over-winter/spring carrot supplies

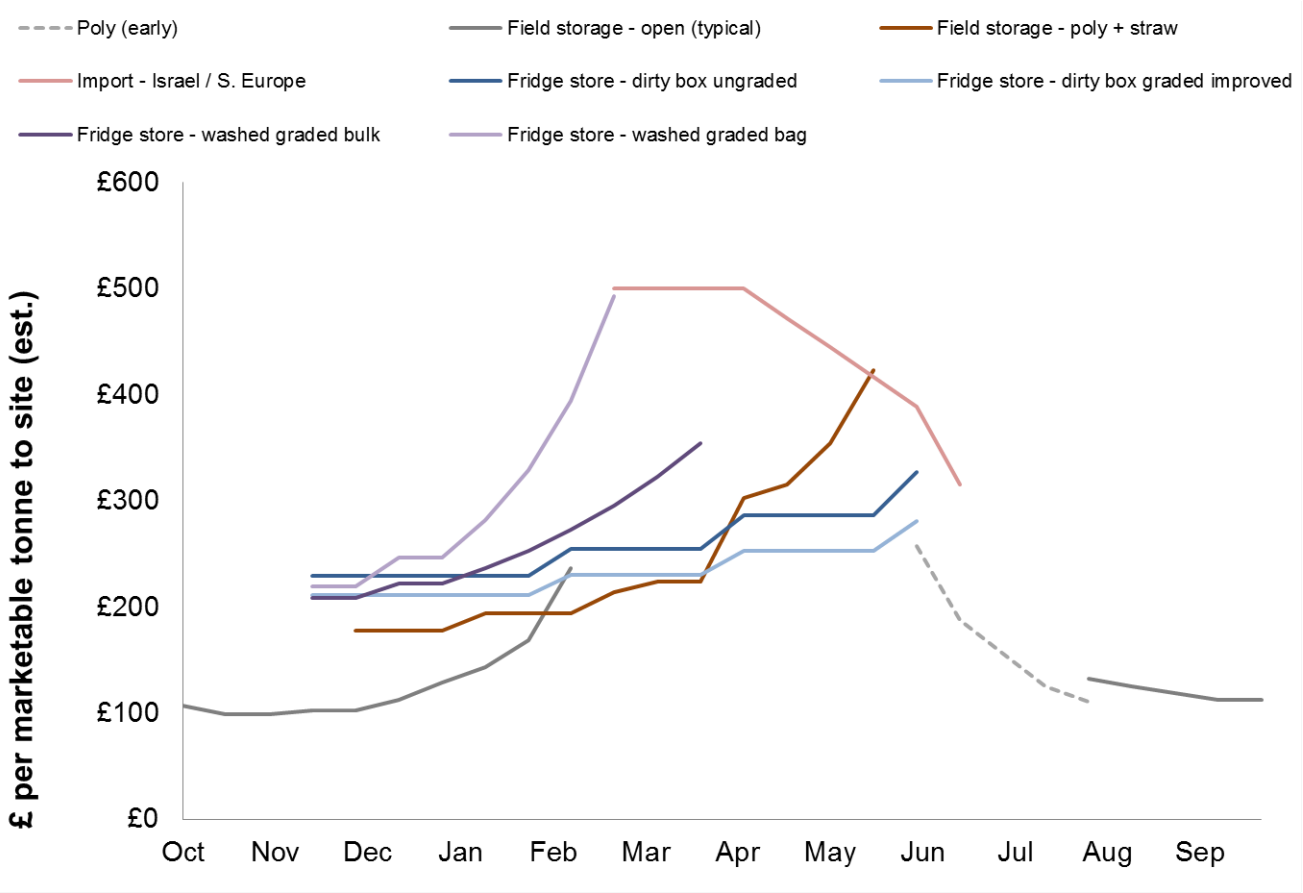


Figure 2 Cost comparison of all refrigerated store and import methods for over-winter/spring carrot supplies (NB standard poly+straw included for comparison).

Although the data collated and evaluated during this desk study is intended to act only as a focus for further discussion on carrot storage / off-season supply within the UK carrot industry, a number of trends are nevertheless apparent and are highlighted below.

There may be some opportunities for greater use of open-ground or ridged soil storage of carrots, making use of some of the newer, more frost tolerant varieties for supplies in the early/mid period (potentially to March). However, the increasing risk of regrowth, disease, wildlife damage and soil access when frozen with such techniques may limit their applicability to a shorter supply window (January) and certain geographical areas (e.g. coastal areas at southern or middle latitudes).

Field storage under straw (no polyethene) can be used for early winter supplies, but suffers from many of the drawbacks of standard polyethene and straw and can reduce flexibility in supply chain. Consequently, its use is likely to remain limited.

The standard method of field storage under polyethene and straw still appears to provide a reasonable (and familiar) solution to carrot supplies during the winter/spring, but retains its existing problems. Modifications of the system by re-baling straw may have some financial benefits if demand (and therefore price) for straw increases and supplies become limited. However, the benefits are currently quite marginal, other than helping to secure supplies.

There appears to be no alternative biodegradable loose insulating material that may provide an improvement on wheat straw. Other combinable straw materials are likely to realise similar costs for similar or worse insulating/application properties.

Re-usable insulating covers appear to be prohibitively expensive, both in capital cost and in laying/removing/transport/storing. Advances in technology/manufacturing process and/or large volume purchasing may reduce capital outlay to a reasonable level, but it is not expected that this method would become viable in the near future.

Imported carrots during the off-season are currently a necessity in the majority of years when UK crop does not quite provide sufficient supplies of quality produce in the overlap between stored carrots and fresh poly carrots. It is likely that this will remain the case in the near future. However, imported produce is typically expensive, subject to volatile market prices and is seen by many as not being very environmentally friendly. Notwithstanding price, it is very unlikely that the UK market would wish to see an increase in imports to cover a greater period of winter/spring demand!

Refrigerated storage of dirty carrots in boxes (as practiced in N Europe) is generally a more expensive option than field storage under straw, although it may match price towards the end of the season (perhaps with decrease in crop skin finish). Two factors may severely limit its use in the UK: limited silty soil resources; and the requirement for large volumes of crop to be harvested and loaded to store in a short period. The latter can be solved with sufficient additional harvesting equipment and continuous shift patterns, but only at additional cost to the system. Furthermore, box stores are quite wasteful in storing not only large volumes of soil, but also crop that will ultimately be rejected – and they can also be subject to large-scale catastrophic crop failures.

An alternative might be to modify the method, by hand-grading the obvious rejects on the harvester and employing state-of-the-art environmental control systems. This may bring some of the cost issues of box storage down to more realistic levels, but does not solve the shortfall in suitable soil types or other issues.

The current practices of storing carrots washed and graded, either in bulk or in some form of perforated or basic modified atmosphere plastic bag do not appear to provide a solution to the UK issue, being even more resource-hungry at harvest/washing/store loading and not currently providing the longevity or quality to compensate for the additional cost.

There are a number of developments in refrigerated carrot storage which may provide sufficient improvement in disease control and crop quality to allow refrigerated storage to compete better with poly+straw methods. Most of these technologies are not yet commercially tested on carrots:

- Steam sterilisation of washed carrots using an intelligent control system to reduce storage diseases
- Hydrogen peroxide fogging to reduce storage diseases.
- Ethylene scrubbing (carrots are very sensitive to ethylene, either from other crops or from propane-powered forklift exhausts)
- UVC sterilisation of washed carrots to reduce storage diseases
- Modified atmosphere packaging (either in bulk bins, or in smaller units) – techniques for fine-tuning the balance between crop and pathogen respiratory requirements are much more advanced than with previous films.
- The principles of modified atmosphere packaging could be applied on a whole-store scale
- Large advances in environmental control units, both in how units operate (e.g. continuously on variable-speed drive, rather than on-off and improved knowledge of air circulation), and in more accurate control of temperature and RH (e.g. improved “dry” fogging systems)
- Fungicide/chlorine rinses for washed produce may also help reduce disease issues (but regulatory and supermarket acceptance issues).

Taking the available evidence to hand, it is suggested that drastic changes to current practice are not executed. However, it may be worth considering including some areas of alternative supply options within grower/packer supply chains to help manage costs and supplies through the winter/spring period. Examples include: open ground storage with frost tolerant varieties (in suitable location) for early winter supplies; straw, or more likely polyethene and straw for mid to late supplies (with or without some re-baling of used straw). Those with access to suitable soil types may wish to invest in dirty box stores, preferably

with some pre-grading before store and the state-of-the-art environmental management systems, but this is only likely to provide a partial solution to winter/spring supplies. Lastly, work should continue to examine the potential of the emerging technologies to enhance existing storage techniques to be more suitable for the UK market in the future.

Conclusions

This study has collated the available information relating to “off-season” carrot supply, both from the UK and from carrot producing nations worldwide. Each strategy or technique is presented in a one-page data-sheet with detail relating to agronomy, harvesting, storage techniques and costs and is summarised with a list of pros and cons and an overall assessment of its suitability for the UK.

Although the study was intended only to provide an information base from which the subject can be further debated within the industry, or further research can be identified, a few key observations have nevertheless been noted. There are indications that the UK system may benefit from including a proportion of open-ground and/or soil-covered crops in suitable coastal locations using some of the newer more frost tolerant varieties for the early winter supply period. There may also be scope to augment current field poly+straw storage for mid to late winter/spring harvest with an improved dirty box storage system.

It appears that most refrigerated storage systems require some further modifications and adaptations before they can become competitive in the UK market. Fortunately, there are a range of emerging technologies that may provide the potential to sufficiently improve refrigerated storage techniques – but these require further research to commercialise.

Knowledge and Technology Transfer

Information from this study will be presented and discussed directly with the British Carrot Growers Association (BCGA) R&D Committee at their July 2011 meeting.

An article for the HDC News will be written for publication as required in 2011.

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Appendix 1 – basic costings for each carrot supply strategy/technique

Field storage - poly + re-baled straw	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 2,200	Seed highest rate and full fungicide programme
STANDARD GROWING COST - operations	£ 1,750	Full fungicide programme, share lift
STANDARD GROWING COST - overhead and rental	£ 1,900	
Additional inputs	£ 2,715	125bales/ha 50% of @£26 + £3/baled delivery + poly on 25% of area, rest as virgin straw above
Additional operations	£ 1,360	Poly + straw laying (higher cost), straw removal, poly removal / disposal, straw incorporation
	£ 9,925	
TRANSPORT TO PACKHOUSE	*£ 8.00*	*PER TONNE (based on typical 100 mile round trip @£2.00/mile for 25t bulker)*

Field storage - poly + alt. bio-degradable	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water etc		Seed highest rate and full fungicide programme
STANDARD GROWING COST - operations		Full fungicide programme, share lift
STANDARD GROWING COST - overhead and rental		
Additional inputs		NO SUITABLE ALTERNATIVE BIODEGRADABLE LOOSE INSULATING PRODUCT FOUND
Additional operations		
	£ -	
TRANSPORT TO PACKHOUSE		*PER TONNE (based on typical 100 mile round trip @£2.00/mile for 25t bulker)*

Field storage - re-usable cover	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 2,200	Seed highest rate and full fungicide programme
STANDARD GROWING COST - operations	£ 1,750	Full fungicide programme, share lift
STANDARD GROWING COST - overhead and rental	£ 1,900	
Additional inputs	£ 10,000	Re-usable insulation @£5/m2 for equivalent to c45cm loose straw, split over 5 yr = £1/m2
Additional operations	£ 1,040	Estimated to cost £600/ha to cover, rremove, store. Dry material=0.5kg/m2, wet=x2? Transport
	£ 16,890	@ 1kg/m2 = estimated transport of £36/ha each way + disposal at 1/3 of £110/t landfill
TRANSPORT TO PACKHOUSE	*£ 8.00*	*PER TONNE (based on typical 100 mile round trip @£2.00/mile for 25t bulker)*

Import - Israel / S. Europe	Cost £/ha	Comment
March-L June: Israel		Typically £400-450/t delivered, c90% packout
April-June: Spain		Typically more volatile, but £300-650/tonne delivered, c90% packout
L May -June: S France		Typically more volatile, but £300-650/tonne delivered, c90% packout
		Assume a base-line average of £450 falling to £400/tonne delivered
	£ -	
TRANSPORT TO PACKHOUSE		

Fridge store - dirty box ungraded	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 1,700	Reduced seed rate and water but full fungicide programme
STANDARD GROWING COST - operations	£ 2,600	Plough, ridge (no destone), drill, hoe, spray, fert. appn, top lift (cost x2 due to time constraint)
STANDARD GROWING COST - overhead and rental	£ 1,600	Rental as per standard maincrop
Additional fixed cost (store/equipment capital)	£ 5,280	£300/t store build cost (off-set over 10yr), boxes @ £70/t box (off set over 5 yr) over 120t/ha
Variable cost (store running, management)	£ 1,800	£10/tonne electricity from Oct-June + £5/tonne for forklift, management etc over 120t/ha
	£ 12,980	Packout reduced from dutch figures of 60-70% to fit UK market demands
TRANSPORT TO STORE and then to PACKHOUSE	*£ 6.25*	*PER TONNE (based on 2x 50 mile round trip @£1.50/mile for 24t box trailer)*

Fridge store - dirty box graded improved	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 1,700	Reduced seed rate and water but full fungicide programme
STANDARD GROWING COST - operations	£ 3,000	Plough, ridge (no destone), drill, hoe, spray, fert. appn, top lift, grade on harvester to boxes
STANDARD GROWING COST - overhead and rental	£ 1,600	Rental as per standard maincrop
Additional fixed cost (store/equipment capital)	£ 5,390	£350/t store build cost (off-set over 10yr), boxes @ £70/t box (off set over 5 yr) over 110t/ha
Variable cost (store running, management)	£ 1,540	£9/tonne electricity from Oct-June + £5/tonne for forklift, management etc over 110t/ha
	£ 13,230	Lower crop into store and packout increased from dirty box ungraded due to pre-store grading
TRANSPORT TO STORE and then to PACKHOUSE	*£ 6.25*	*PER TONNE (based on 2x 50 mile round trip @£1.50/mile for 24t box trailer)*

Fridge store - washed graded bulk	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 1,700	Reduced seed rate and water but full fungicide programme
STANDARD GROWING COST - operations	£ 2,600	Plough, ridge (no destone), drill, hoe, spray, fert. appn, top lift (cost x2 due to time constraint)
STANDARD GROWING COST - overhead and rental	£ 1,600	Rental as per standard maincrop
Additional fixed cost (store/equipment capital)	£ 3,600	£500/t store/washer build cost (off-set over 10yr) over 72t/ha
Variable cost (store running, management)	£ 2,304	£12/tonne electricity from Oct-June + £20/tonne for labour/mobile machinery etc over 72t/ha
	£ 11,804	Post-harvest washing/grading assumed to be 60% crop to store
TRANSPORT TO STORE and then to PACKHOUSE	*£ 8.00*	*PER TONNE (based on 2x 50 mile round trip @£2/mile for 24t box trailer)*

Fridge store - washed graded bag	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 1,700	Reduced seed rate and water but full fungicide programme
STANDARD GROWING COST - operations	£ 2,600	Plough, ridge (no destone), drill, hoe, spray, fert. appn, top lift (cost x2 due to time constraint)
STANDARD GROWING COST - overhead and rental	£ 1,600	Rental as per standard maincrop
Additional fixed cost (store/equipment capital)	£ 4,320	£600/t store/washer build cost (off-set over 10yr) over 72t/ha
Variable cost (store running, management)	£ 3,024	£12/tonne electricity from Oct-June + £30/tonne for labour/mobile machinery etc over 72t/ha
	£ 13,244	Post-harvest washing/grading assumed to be 60% crop to store
TRANSPORT TO STORE and then to PACKHOUSE	*£ 8.00*	*PER TONNE (based on 2x 50 mile round trip @£2/mile for 24t box trailer)*

Poly (early)	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 1,700	Seed higher rate, little herbicide programme, no fungicide programme, inc poly
STANDARD GROWING COST - operations	£ 1,830	Few sprays, top lift
STANDARD GROWING COST - overhead and rental	£ 1,600	
	£ 5,130	
TRANSPORT TO PACKHOUSE	*£ 8.00*	*PER TONNE (based on typical 100 mile round trip @£2.00/mile for 25t bulker)*

Field storage - open (typical)	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 2,060	Seed higher rate and full fungicide programme
STANDARD GROWING COST - operations	£ 1,700	Full fungicide programme, mostly share lift
STANDARD GROWING COST - overhead and rental	£ 1,600	
	£ 5,360	
TRANSPORT TO PACKHOUSE	*£ 8.00*	*PER TONNE (based on typical 100 mile round trip @£2.00/mile for 25t bulker)*

Field storage - open (FTV)	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 2,160	Seed slightly reduced rate, but higher price and full fungicide programme
STANDARD GROWING COST - operations	£ 1,700	Full fungicide programme, mostly share lift
STANDARD GROWING COST - overhead and rental	£ 1,600	
	£ 5,460	
TRANSPORT TO PACKHOUSE	*£ 8.00*	*PER TONNE (based on typical 100 mile round trip @£2.00/mile for 25t bulker)*

Field storage - soil covered	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 1,990	Seed reduced rate and full fungicide programme
STANDARD GROWING COST - operations	£ 1,790	Full fungicide programme, share lift
STANDARD GROWING COST - overhead and rental	£ 1,810	
Additional operations	£ 150	Ridging soil over beds
	£ 5,740	
TRANSPORT TO PACKHOUSE	*£ 8.00*	*PER TONNE (based on typical 100 mile round trip @£2.00/mile for 25t bulker)*

Field storage - soil covered (FTV)	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 2,090	Seed reduced rate and full fungicide programme
STANDARD GROWING COST - operations	£ 1,790	Full fungicide programme, share lift
STANDARD GROWING COST - overhead and rental	£ 1,810	
Additional operations	£ 150	Ridging soil over beds
	£ 5,840	
TRANSPORT TO PACKHOUSE	*£ 8.00*	*PER TONNE (based on typical 100 mile round trip @£2.00/mile for 25t bulker)*

Field storage - straw only	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 2,200	Seed highest rate and full fungicide programme
STANDARD GROWING COST - operations	£ 1,750	Full fungicide programme, share lift
STANDARD GROWING COST - overhead and rental	£ 1,810	
Additional inputs	£ 2,300	100bales/ha @£23
Additional operations	£ 800	Straw laying, removal, incorporation
	£ 8,860	
TRANSPORT TO PACKHOUSE	*£ 8.00*	*PER TONNE (based on typical 100 mile round trip @£2.00/mile for 25t bulker)*

Field storage - poly + straw	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 2,200	Seed highest rate and full fungicide programme
STANDARD GROWING COST - operations	£ 1,750	Full fungicide programme, share lift
STANDARD GROWING COST - overhead and rental	£ 1,900	
Additional inputs	£ 2,790	100bales/ha @£23 + poly
Additional operations	£ 1,240	Poly + straw laying, straw removal, poly removal / disposal, straw incorporation
	£ 9,880	
TRANSPORT TO PACKHOUSE	*£ 8.00*	*PER TONNE (based on 100 mile round trip @£2.00/mile for 25t bulker until April, then £32/t from Scotland)*

Field storage - poly + straw (re-bale)	Cost £/ha	Comment
STANDARD GROWING COST - seed/fert/chemical/water e	£ 2,200	Seed highest rate and full fungicide programme
STANDARD GROWING COST - operations	£ 1,750	Full fungicide programme, share lift
STANDARD GROWING COST - overhead and rental	£ 1,900	
Additional inputs	£ 2,790	100bales/ha @£23 + poly
Additional operations	£ 1,575	Poly + straw laying, poly removal / disposal, straw windrow/bale @ 50% of £26/bale, 40 bales/ha
	£ 10,215	(assuming either re-used and costs split between years or biomass value of £15-20/tonne)
TRANSPORT TO PACKHOUSE	*£ 8.00*	*PER TONNE (based on typical 100 mile round trip @£2.00/mile for 25t bulker)*

Appendix 2 – annual calculation of production costs for each supply strategy/technique

Poly (early)

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha)																		35	45	55	70	80				
% packout																		60%	65%	65%	65%	65%				
Marketable (t/ha)																		21.0	29.3	35.8	45.5	52.0				
Estimated production cost (/ha)																		£5,410	£5,490	£5,570	£5,690	£5,770				
Estimated production cost (/t)																		£258	£188	£156	£125	£111				

Field storage - open (typical) (Maincrop)

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha)	95	95	95	100	100	100	95	95	90	85												75	80	85	90	90
% packout	60%	65%	65%	60%	60%	55%	50%	45%	40%	30%												60%	60%	60%	60%	60%
Marketable (t/ha)	57.0	61.8	61.8	60.0	60.0	55.0	47.5	42.8	36.0	25.5												45.0	48.0	51.0	54.0	54.0
Estimated production cost (/ha)	£6,120	£6,120	£6,120	£6,160	£6,160	£6,160	£6,120	£6,120	£6,080	£6,040												£5,960	£6,000	£6,040	£6,080	£6,080
Estimated production cost (/t)	£107	£99	£99	£103	£103	£112	£129	£143	£169	£237												£132	£125	£118	£113	£113

Field storage - open (FTV) (Maincrop with Frost Tolerant Varieties)

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha)			85	90	90	90	90	85	80	75	75															
% packout			60%	60%	60%	60%	55%	55%	50%	45%	40%															
Marketable (t/ha)			51.0	54.0	54.0	54.0	49.5	46.8	40.0	33.8	30.0															
Estimated production cost (/ha)			£6,140	£6,180	£6,180	£6,180	£6,180	£6,140	£6,100	£6,060	£6,060															
Estimated production cost (/t)			£120	£114	£114	£114	£125	£131	£153	£180	£202															

Field storage - soil covered

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha)				80	80	80	80	75	75	70	70	65														
% packout				65%	65%	65%	60%	60%	55%	50%	45%	40%														
Marketable (t/ha)				52.0	52.0	52.0	48.0	45.0	41.3	35.0	31.5	26.0														
Estimated production cost (/ha)				£6,380	£6,380	£6,380	£6,380	£6,340	£6,340	£6,300	£6,300	£6,260														
Estimated production cost (/t)				£123	£123	£123	£133	£141	£154	£180	£200	£241														

Field storage - soil covered (FTV) Soil covered crop with Frost Tolerant Variety)

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha)				70	70	70	70	70	70	65	65	60	60													
% packout				65%	65%	65%	65%	60%	60%	55%	50%	45%	40%													
Marketable (t/ha)				45.5	45.5	45.5	45.5	42.0	42.0	35.8	32.5	27.0	24.0													
Estimated production cost (/ha)				£6,400	£6,400	£6,400	£6,400	£6,400	£6,400	£6,360	£6,360	£6,320	£6,320													
Estimated production cost (/t)				£141	£141	£141	£141	£152	£152	£178	£196	£234	£263													

Field storage - straw only (100 hestons/ha @£23/bale)

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha)					100	100	100	100	100	95	95	90	85	80												
% packout					60%	60%	55%	55%	55%	50%	45%	45%	40%	35%												
Marketable (t/ha)					60.0	60.0	55.0	55.0	55.0	47.5	42.8	40.5	34.0	28.0												
Estimated production cost (/ha)					£9,660	£9,660	£9,660	£9,660	£9,660	£9,620	£9,620	£9,580	£9,540	£9,500												
Estimated production cost (/t)					£161	£161	£176	£176	£176	£203	£225	£237	£281	£339												

Field storage - poly + straw (100 hestons/ha @£23/bale)

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha)					100	100	100	100	100	100	100	95	95	95	90	90	85									
% packout					60%	60%	60%	55%	55%	55%	50%	50%	50%	45%	45%	40%	35%									
Marketable (t/ha)					60.0	60.0	60.0	55.0	55.0	55.0	50.0	47.5	47.5	42.8	40.5	36.0	29.8									
Estimated production cost (/ha)					£10,680	£10,680	£10,680	£10,680	£10,680	£10,680	£10,680	£10,640	£10,640	£12,920	£12,760	£12,760	£12,600									
Estimated production cost (/t)					£178	£178	£178	£194	£194	£194	£214	£224	£224	£302	£315	£354	£424									

Field storage - poly + straw (re-bale) (100 hestons/ha @£23/bale)

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha)					100	100	100	100	100	100	100	95	95	95	90	90	85									
% packout					60%	60%	60%	55%	55%	55%	50%	50%	50%	45%	45%	40%	35%									
Marketable (t/ha)					60.0	60.0	60.0	55.0	55.0	55.0	50.0	47.5	47.5	42.8	40.5	36.0	29.8									
Estimated production cost (/ha)					£11,015	£11,015	£11,015	£11,015	£11,015	£11,015	£11,015	£10,975	£10,975	£10,975	£10,935	£10,935	£10,895									
Estimated production cost (/t)					£184	£184	£184	£200	£200	£200	£220	£231	£231	£257	£270	£304	£366									

Field storage - poly + re-baled straw (125 hesstons/ha @£26/bale)

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha)					100	100	100	100	100	100	100	95	95	95	90	90	85									
% packout					60%	60%	60%	55%	55%	55%	50%	50%	50%	45%	45%	40%	35%									
Marketable (t/ha)					60.0	60.0	60.0	55.0	55.0	55.0	50.0	47.5	47.5	42.8	40.5	36.0	29.8									
Estimated production cost (/ha)					£10,725	£10,725	£10,725	£10,725	£10,725	£10,725	£10,725	£10,685	£10,685	£10,685	£10,645	£10,645	£10,605									
Estimated production cost (/t)					£179	£179	£179	£195	£195	£195	£215	£225	£225	£250	£263	£296	£356									

Field storage - poly + alt. bio-degradable Alternative loose biodegradable product

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha)					100	100	100	100	100	100	100	95	95	95	90	90	85									
% packout					60%	60%	60%	55%	55%	55%	50%	50%	50%	45%	45%	40%	35%									
Marketable (t/ha)					60.0	60.0	60.0	55.0	55.0	55.0	50.0	47.5	47.5	42.8	40.5	36.0	29.8									
Estimated production cost (/ha)					£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0									
Estimated production cost (/t)					£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0									

Field storage - re-usable cover Synthetic re-usable insulatgn cover

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha)					100	100	100	100	100	100	100	95	95	95	90	90	85									
% packout					60%	60%	60%	55%	55%	55%	50%	50%	50%	45%	45%	40%	35%									
Marketable (t/ha)					60.0	60.0	60.0	55.0	55.0	55.0	50.0	47.5	47.5	42.8	40.5	36.0	29.8									
Estimated production cost (/ha)					£17,690	£17,690	£17,690	£17,690	£17,690	£17,690	£17,690	£17,650	£17,650	£17,650	£17,610	£17,610	£17,570									
Estimated production cost (/t)					£295	£295	£295	£322	£322	£322	£354	£372	£372	£413	£435	£489	£591									

Import - Israel / S. Europe

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha)											1	1	1	1	1	1	1	1	1							
% packout											90%	90%	90%	90%	90%	90%	90%	90%	95%							
Marketable (t/ha)											0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.0							
Estimated production cost (/ha)											£450	£450	£450	£450	£425	£400	£375	£350	£300							
Estimated production cost (/t)											£500	£500	£500	£500	£472	£444	£417	£389	£316							

Fridge store - dirty box ungraded (Standard N European type box store)

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha) (inc 25% soil)				120	120	120	120	120	120	120	120	120	120	120	120	120	120	120								
% packout (for UK market)				50%	50%	50%	50%	50%	50%	45%	45%	45%	45%	40%	40%	40%	40%	35%								
Marketable (t/ha)				60.0	60.0	60.0	60.0	60.0	60.0	54.0	54.0	54.0	54.0	48.0	48.0	48.0	48.0	42.0								
Estimated production cost (/ha)				£13,730	£13,730	£13,730	£13,730	£13,730	£13,730	£13,730	£13,730	£13,730	£13,730	£13,730	£13,730	£13,730	£13,730	£13,730								
Estimated production cost (/t)				£229	£229	£229	£229	£229	£229	£254	£254	£254	£254	£286	£286	£286	£286	£327								

Fridge store - dirty box graded improved (Improved N European type)

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha) (inc 25% soil)				110	110	110	110	110	110	110	110	110	110	110	110	110	110	110								
% packout (for UK market)				60%	60%	60%	60%	60%	60%	55%	55%	55%	55%	50%	50%	50%	50%	45%								
Marketable (t/ha)				66.0	66.0	66.0	66.0	66.0	66.0	60.5	60.5	60.5	60.5	55.0	55.0	55.0	55.0	49.5								
Estimated production cost (/ha)				£13,918	£13,918	£13,918	£13,918	£13,918	£13,918	£13,918	£13,918	£13,918	£13,918	£13,918	£13,918	£13,918	£13,918	£13,918								
Estimated production cost (/t)				£211	£211	£211	£211	£211	£211	£230	£230	£230	£230	£253	£253	£253	£253	£281								

Fridge store - washed graded bulk (Common in USA and Canada)

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha) (inc 25% soil)				120	120	120	120	120	120	120	120	120	120													
% post-harvest wash gradout				60%	60%	60%	60%	60%	60%	60%	60%	60%	60%													
Graded crop to store				72	72	72	72	72	72	72	72	72	72													
% packout of graded after store				85%	85%	80%	80%	75%	70%	65%	60%	55%	50%													
Marketable (t/ha)				61.2	61.2	57.6	57.6	54.0	50.4	46.8	43.2	39.6	36.0													
Estimated production cost (/ha)				£12,764	£12,764	£12,764	£12,764	£12,764	£12,764	£12,764	£12,764	£12,764	£12,764													
Estimated production cost (/t)				£209	£209	£222	£222	£236	£253	£273	£295	£322	£355													

Fridge store - washed graded bag (Temp. storage occasionally longer in USA)

Week	41	43	45	47	49	51	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39
Date	10-Oct	24-Oct	07-Nov	21-Nov	05-Dec	19-Dec	02-Jan	16-Jan	30-Jan	13-Feb	27-Feb	12-Mar	26-Mar	09-Apr	23-Apr	07-May	21-May	04-Jun	18-Jun	02-Jul	16-Jul	30-Jul	13-Aug	27-Aug	10-Sep	24-Sep
Yield (t/ha) (inc 25% soil)				120	120	120	120	120	120	120	120															
% post-harvest wash gradout				60%	60%	60%	60%	60%	60%	60%	60%															
Graded crop to store				72	72	72	72	72	72	72	72															
% packout of graded after store				90%	90%	80%	80%	70%	60%	50%	40%															
Marketable (t/ha)				64.8	64.8	57.6	57.6	50.4	43.2	36.0	28.8															
Estimated production cost (/ha)				£14,204	£14,204	£14,204	£14,204	£14,204	£14,204	£14,204	£14,204															
Estimated production cost (/t)				£219	£219	£247	£247	£282	£329	£395	£493															