Grower Summary

FV 398b

Practical evaluation of carrot field storage alternatives

Annual 2016

Disclaimer

The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

Use of pesticides

Only officially approved pesticides may be used in the UK. Approvals are normally granted only in relation to individual products and for specified uses. It is an offence to use non-approved products or to use approved products in a manner that does not comply with the statutory conditions of use, except where the crop or situation is the subject of an off-label extension of use.
Before using all pesticides check the approval status and conditions of use.
Read the label before use: use pesticides safely.

Further information

If you would like a copy of the full report, please email the AHDB Horticulture office (hort.info.@ahdb.org.uk), quoting your AHDB Horticulture number, alternatively contact AHDB Horticulture at the address below.

AHDB Horticulture,
AHDB
Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

Tel – 0247 669 2051

AHDB Horticulture is a Division of the Agriculture and Horticulture Development Board.

Project title:	Practical evaluation of carrot field storage alternatives
Project number:	FV 398b
Project leader:	Dr S J Roberts, Plant Health Solutions Ltd
Report:	Annual report, December 2016
Previous report:	None
Key staff:	Dr S J Roberts (PHS) James Howell (VCS)
Location of project:	VCS, Wellbeck; PHS, Warwick; Trial sites in Norfolk, Aberdeenshire, Yorkshire.
Industry Representative:	Mr Rodger Hobson
Date project commenced:	01 August 2015
Date project completion due:	30 September 2017

GROWER SUMMARY

Headline

All of the reduced-straw and non-straw alternatives provided adequate frost-protection for field-stored carrot crops during the winter of 2015-16.

Background

Current UK industry practice is to store carrots for winter / spring marketing *in-situ* in the field, typically covered with a thick layer of straw (with or without an additional layer of polythene below) to provide insulation against frost damage during the winter and to prevent warming and re-growth in the spring. However, field storage using straw is becoming increasingly problematical and challenged as a sustainable technique - largely due to the high cost and volatile availability of straw, but also due to agronomic issues such as nutrient lock-up from the decomposition of incorporated straw after carrot harvest, and the potential for introduction of problem weed seeds with the straw. With the continued development of straw-fired biomass plants, increasing pressure on cereal farmers to re-incorporate organic matter rather than remove it as straw, the volatility of the cereal market and the effects of climate change, supplies of straw are likely to become both more expensive and erratic in future years. In addition, landowners have a major concern that importing straw may introduce blackgrass seeds into fields which have been previously free. Although not considered a severe problem on sandy (carrot) soils, there is a fear that once present on a farm it could move on to other fields with heavier soil.

There is therefore a demand to examine alternative options for in-field storage of carrots which do not rely on the use of large quantities of straw, either reduced quantities of straw or non-straw alternatives. A previous project, (FV 398a), primarily a theoretical desk-based study, investigated:

- heat transfer principles involved in field storage
- the theoretical insulation value of current methods
- the cost and issues involved in using alternative insulation materials

The project identified inefficiencies (in terms of insulative value) in the current straw-based systems, some possible misconceptions, and alternative systems and materials that could have equivalent or better insulative value to the current system. However, estimates of insulative value of alternative systems were theoretical, therefore this project aims to provide:

(a) practical validation of the theoretical insulative values for alternative materials and their impact on crop quality, and

(b) to begin investigations of practical implementation of alternative systems.

Summary

Field trials were established in commercial strawed crops of cv. Nairobi. Six treatments (untreated control plus five others) (Table 1, Figure 1) were examined at three different locations (Norfolk, Scotland and Yorkshire) and with two harvest dates. Each plot was 7 or 8-beds wide by 10 m long. Soil temperature and moisture sensors were inserted into each plot at depths of up to 50 cm and relayed hourly data records via the mobile-phone network. In addition, two speculative, non-replicated treatments were also included at the Yorkshire site.

Table 1. Treatment codes and details.

Code	Treatment	Details/Notes
A	Uncovered control	Untreated control.
B	Straw alone	Standard covering of straw (commercial standard).
C	Straw over polythene	Straw with a single layer of black polythene below (commercial standard)
D	Reduced straw polythene sandwich	Reduced (approx 1/3rd, ~1.5 kg/m^2) amount of straw with layer of black polythene below and layer of black polythene over the top.
E	Cellulose fibre polythene sandwich	Cellulose fibre, approx 5 cm depth, 1.75 kg/m^2 with a layer of black polythene below and a layer of white polythene over the top.
F	Closed cell PE Foam	Natural/white coloured, closed cell polyethylene foam, 7.5 mm thick, with a layer of white polythene over the top to provide anchorage.

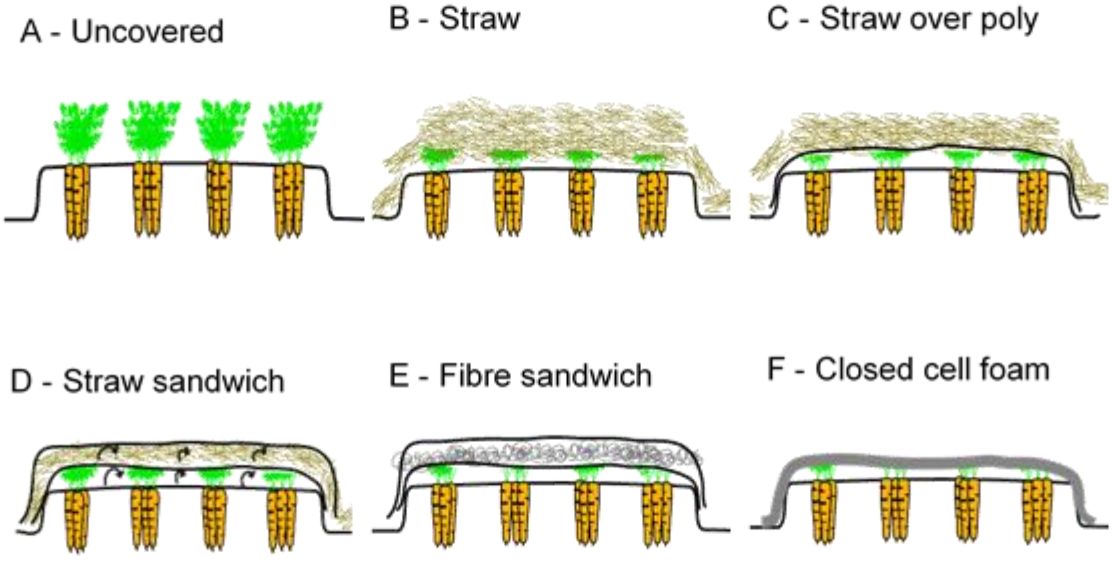

Figure 1. Diagram demonstrating each of the treatments.

All of the treatments provided effective frost protection in the winter of 2015-16, although this was generally a mild winter. The only significant frost damage occurred in the uncovered control (A) and in additional fleece-covered plots at the Yorkshire site. The levels of total damage (frost-damage and crown-rots) are shown in in Figure 2. The average and range of temperatures for each site and treatment are shown in Figure 3 and the average U-values (measures of insulation value) are shown in in Figure 4 for both heat loss and heat gain by the soil.

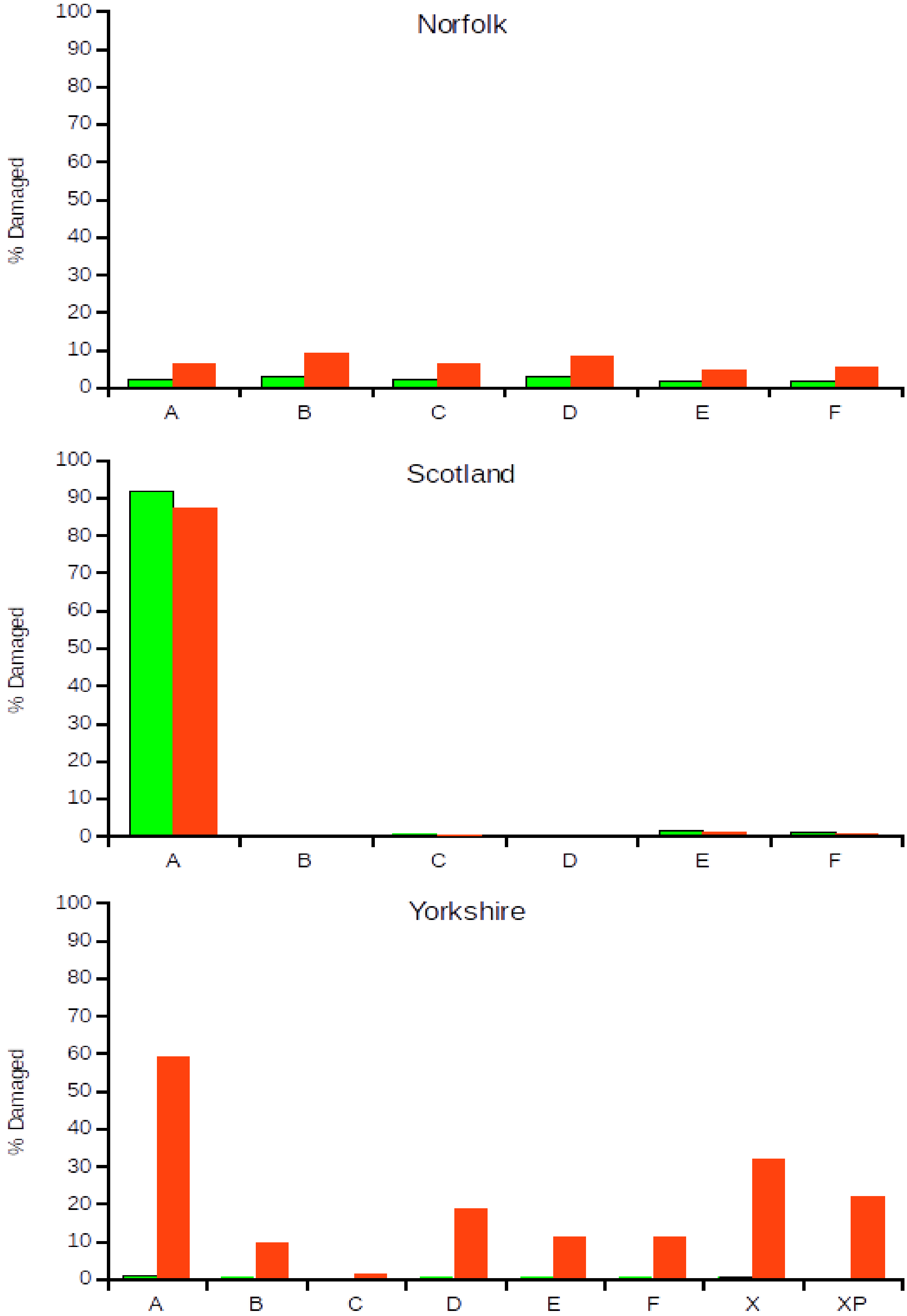

Figure 2. The percentage of damaged carrot roots at each harvest in each treatment at each site. Green (left hand) bars represent the first harvest, red (right hand) bars represent the second harvest.

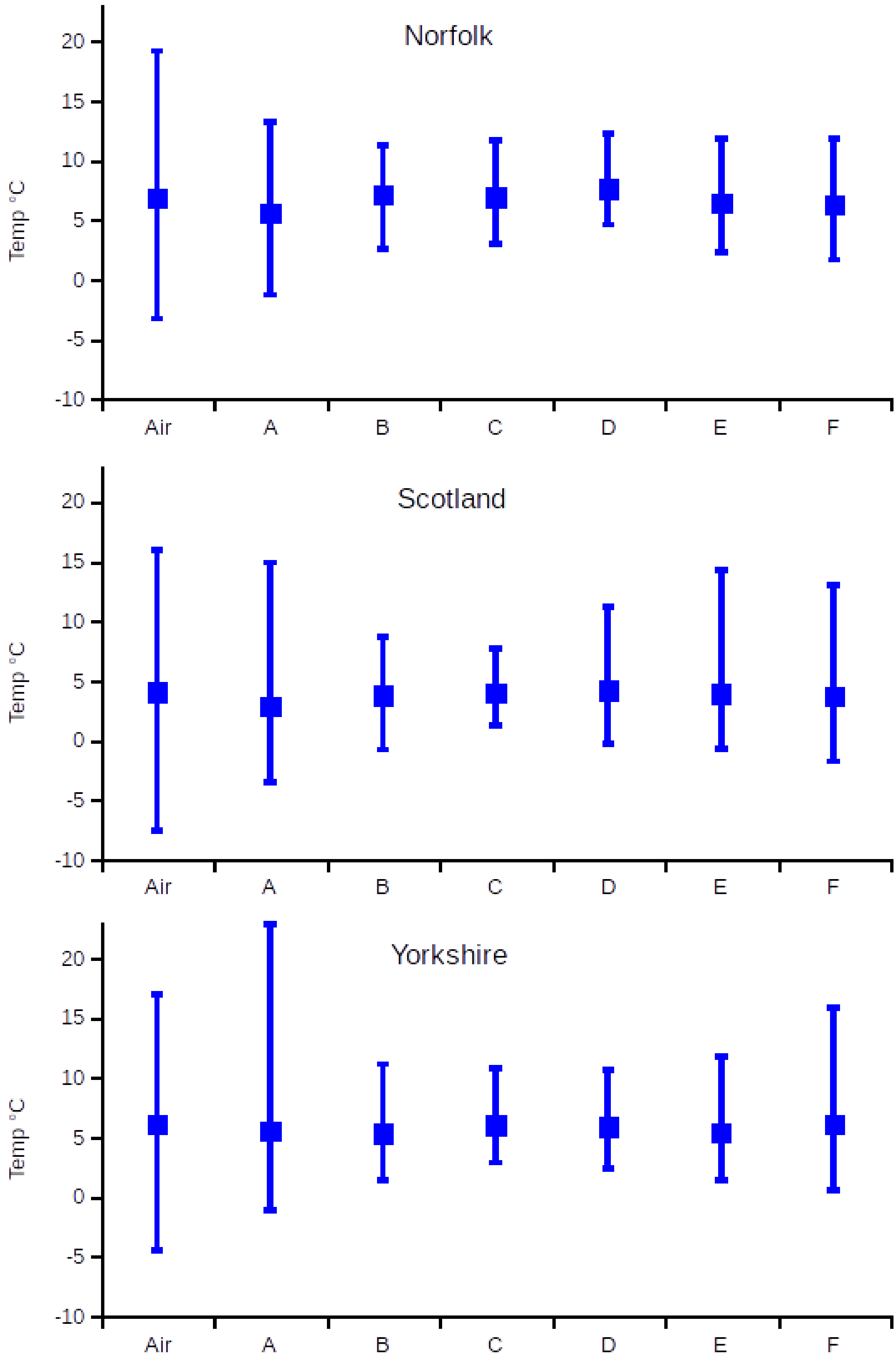

Figure 3. The effect of treatment on the soil surface temperature at each site. The square symbol represents the average, the bars represent the maxima and minima. Air temperature is also shown on the left for reference.

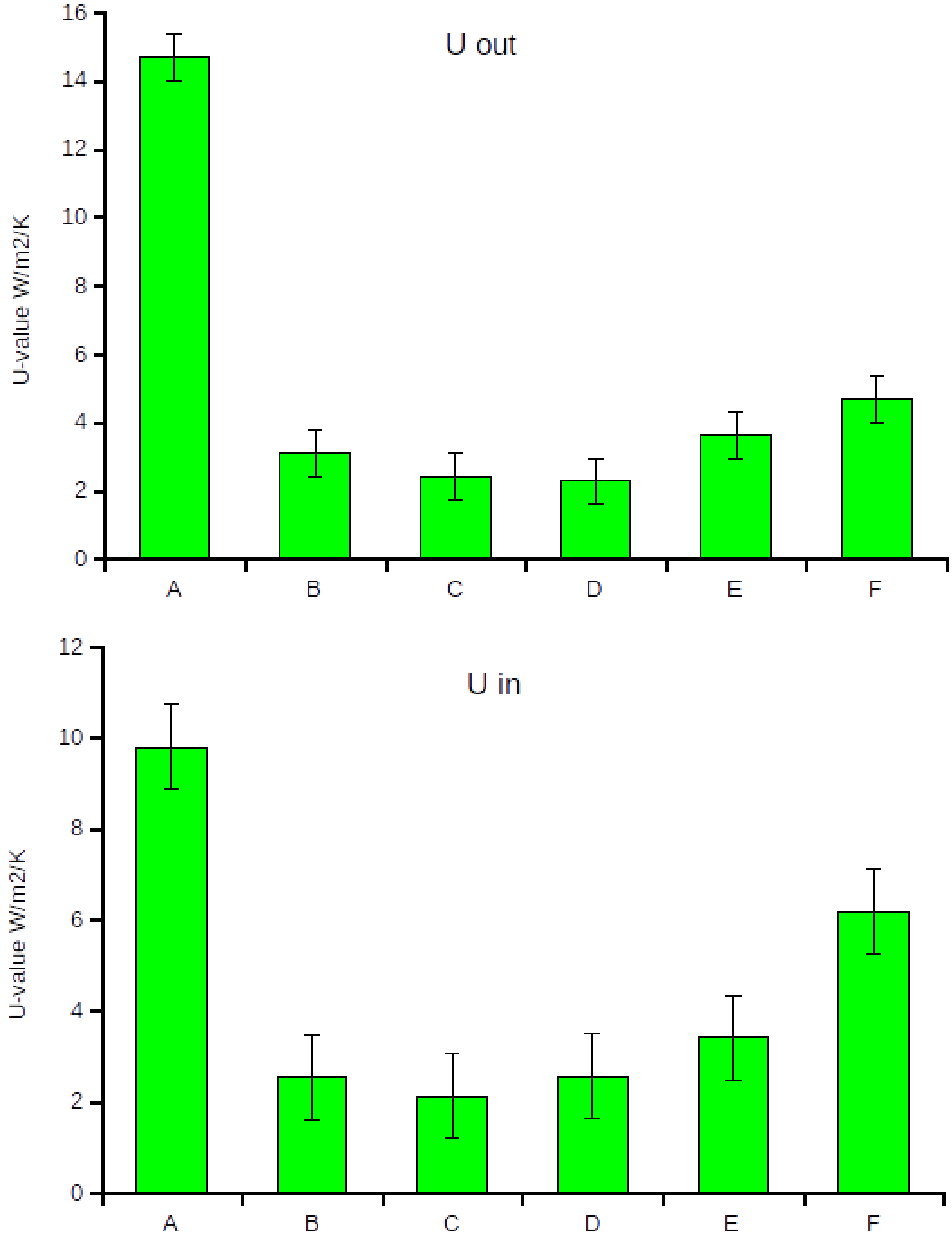

Figure 4. The effect of treatment on the estimated outgoing (soil losing heat) and incoming (soil gaining heat) U-values. A low U-value indicates a good insulator.

Some notes and comments on each of the treatments are given below:

Treatment B (straw alone)

This treatment was included as a commercial standard and to obtain baseline data for current practice. This treatment provided slightly less insulation than treatment C. The straw remains wet at the bottom (but not as wet as treatment C). This has two effects: providing a thermal mass effect (dampening of temperature fluctuations, and the water in the straw will freeze before the soil/crop), and providing potential for evaporative cooling. We suspect that the thermal mass effect may be an important aspect of the protection provided. The soil in the beds was wetter in this treatment than the others which all had a covering of polythene.

Treatment C (straw-over-poly)

This treatment was included as a positive control and a commercial standard, to obtain baseline data for current practice and to understand more about the role and benefits or otherwise of the polythene layer. The introduction of a polythene layer provides additional insulation. The presence of the polythene also means that the straw remains much wetter than treatment B (about twice the moisture content), often with free water on the surface of the polythene. This larger amount of water provides a greater thermal mass and greater potential for evaporative cooling. Thus, not only does this mean that the crop is more protecting from freezing, but also heats up less slowly in the spring (i.e. is kept within a narrower temperature range than the other treatments). Hence treatment C appeared to be the most effective insulation against incoming heat.

In the previous project (FV 398a) growers often reported that the main benefit of the polythene under straw was light-exclusion to prevent re-growth. There is no evidence that light-exclusion prevents re-growth of carrots, and all the evidence suggests that it is entirely temperature driven. Experience in this project supports this: light exclusion did not prevent re-growth but simply resulted in more yellow and etiolated foliage rather than green normal foliage. It is likely that the beneficial effect of the polythene perceived by growers has little to do with light exclusion and is primarily a result of the greater thermal mass, and evaporative cooling effects.

Treatment D (reduced straw poly sandwich)

This treatment provided the most effective insulation against heat loss from the soil. Theoretical estimates of U-values in the previous project (FV 398a) indicated that the open surface of the traditional straw treatments was an inefficient use of the insulation material due to mass transfer of air and ingress of water. The estimates suggested that the amount of straw used per ha could be reduced by about 2/3rds by putting the straw in a polythene sandwich. These results support the earlier theoretical predictions. However, the presence of a moisture barrier over the top, means that in the spring there is no opportunity for evaporative cooling and so this treatment ranked slightly behind treatment C for incoming insulation value.

Treatment E (cellulose-fibre poly sandwich)

This treatment was identified as one of the cheapest and most realistic non-straw alternatives in the previous project (FV 398a). It consisted of a 5cm deep layer of 'fluffed-up' cellulose fibre sandwiched between two layers of polythene. Any residue will break down in the soil in a similar way to straw (except likely to be more rapid due to greater exposed surface area) and it was used at a lower rate (1.75 kg/m^2) than straw (5 kg/m^2), so will have less impact on nitrogen availability for the following crop. It ranked slightly behind the straw treatments (B, C, D) in terms of insulation value, but not significantly so, and still provided adequate insulation for the crop at all sites. The intention with this treatment was that the cellulose fibre would remain dry to maximise its insulation value, and the predicted U-values were expected to be similar to treatment D. However it generally became very saturated with water (absorbing 400 to 600% of its dry weight) due to ingress of water under the polythene cover, reducing its intrinsic insulation value. However, this meant that this treatment also provided the greatest thermal mass, and it is possible that this provided most, if not all, of the frost protection. Indeed on occasion when visiting sites it was noted that the top 1 or 2 cm of insulation material was frozen, although the layer below was not and the crop was fine.

Concern has been expressed about the possible presence of heavy metals in the material; the supplier provided analyses of the material (required for EC health and safety requirements when it is used for house insulation) which indicated levels were below the limits of detection of the analytical methods.

Treatment F (closed-cell foam)

This treatment was included as a non-straw alternative and consisted of a single 7.5 mm thick natural/white closed-cell polyethylene foam laid directly over the crop and secured with a wider layer of white polythene. The material is relatively expensive and would only be cost-effective if re-used. It is available in different thickness, but thicker versions increase cost, we therefore examined the thinnest version with a view to using it on its own for earlier harvests or as an adjunct to other materials. The great advantage of this material is that the closed-cell nature (i.e. air is trapped in closed-cells) means that its insulation properties are unaffected by moisture. Based on the theoretical predictions it was expected that this treatment would have the lowest insulation value, and this proved to be the case, nevertheless it still provided adequate protection at all sites, and we were able to recover it intact for re-use at all sites.

One aspect of this treatment not anticipated was that both it and the polythene cover were translucent. This meant that unlike in all the other treatments, the crop foliage remained green throughout, although this did not have any noticeable/measurable direct effect on crop quality either way.

Treatment X and XP (black fleece and fleece plus polythene)

Two additional treatments were also examined at the Yorkshire site (i.e. without replication) on a speculative basis without the detailed temperature records. These treatments consisted of a black thermal fleece alone (X) or with an additional cover of black polythene (XP). Significant frost damage occurred in both these treatments, and although this was less than in the uncovered plot, it was unacceptably high and reduced marketable yield. Whilst such a treatment may provide some protection in milder conditions or for short term crops, but we suspect that one or two layers of much cheaper polythene sheet would provide a much more cost-effective solution.

Conclusions

- Treatments B-F provided effective 'insulation' in the year 2015-16.
- Although the current straw treatments are inefficient in pure insulation terms, it is possible that a significant part of the frost protection provided results from retention of water in the straw-layer. This provides a greater thermal mass (reducing temperature fluctuations) and reduces freezing due to latent heat of fusion.
- Having a layer of polythene below the straw as well as providing another layer of insulation results in greater water retention in the straw layer, increasing its thermal mass, and increasing the potential for evaporative cooling.
- There is no evidence that light-exclusion by the polythene has any impact on crop quality.
- Covering straw with a second layer of polythene allows the amount of straw to be reduced by about 2/3rds, whilst achieving a better level of insulation.
- The two non-straw alternatives: cellulose fibre and closed-cell PE foam both provided adequate frost protection.
- Closed-cell PE foam could easily be used as a supplemental layer in the current system if straw is in short supply.

Financial Benefits

The area of carrots stored under straw is estimated at around 3-4000 ha per annum. Current estimates for the costs of straw-based field storage systems are around £30 per 500 kg Hesston bale (delivered to field), applied at 80-120 bales/ha. With application and removal included, the technique costs around £4000-5000 per ha on top of crop production and harvesting costs. However, almost as important as cost is the vulnerability of straw supply.

We have identified that a reduction in straw usage of up 2/3rds could be achievable by using a poly-straw-poly sandwich system. This could amount to a saving of £2000 per ha, equivalent to at least £6 million per annum for the industry as a whole.

Action Points

- Growers wishing to reduce straw usage could consider moving to a poly-straw-sandwich using 1/3rd the normal amount of straw.