AHDB

HORTICULTURE

Grower Summary

SF 171

Enhancing the profitability of rhubarb using spectral modifications

Final 2020

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1 Grower Summary

1.1 Headline

- Both blue and opaque plastic may significantly bring forward the harvestable window for green-pull rhubarb, while offering significant enhancement of marketable qualities.

1.2 Background and expected deliverables

Rhubarb is a high value crop grown over 500 ha in the UK, producing 21,000 tonnes in 2018. The marketed product, the leaf petioles with a strong red pigmentation (or 'sticks'), are harvested from perennial crowns in the spring. Desirable traits include a long and slender habit with a snappy, non-fibrous texture. Forced and green pull rhubarb is often considered a separate product.

Conventional rhubarb is harvested from crowns grown in the open field from Feb/March into early summer, but this tends to be of lower value due to thicker petioles with prominent fibres and significant greening. Customer demand (in terms of both early season supply and high quality petioles) can be more directly met with forced rhubarb whereby mature crowns are lifted in the early spring and kept in near-complete darkness with controlled temperatures. The lack of light curtails normal petiole development, causing petioles to rapidly elongate without developing any significant leaf. The lack of light also prevents the petioles from greening up, giving a strong red colour and strong flavour. This produces a product of optimum quality which can be marketed 3 – 4 months before green-pull rhubarb is ready for harvest.

However, crowns are exhausted by this forcing and must be replaced with fresh crowns the following season. Forcing sheds can be expensive facilities to maintain, particularly as they cannot easily be repurposed for the rest of the year. When combined with the significant labour costs of lifting, overall production costs can be increased by £11k/ha, although forced rhubarb can be worth 5 – 6 times more than that of green pull rhubarb due to the greater market quality and early season supply.

Labour remains one of the greatest costs of production across horticulture. This cost has been overcome by increased automation in many crops, particularly during harvesting. However, in the case of rhubarb, harvesting still has to be done by hand, particularly in selective pulls where only harvestable petioles are taken leaving immature sticks in the ground for later harvests. As a result, rhubarb growers have not gained the cost savings during harvest that are achieved by growers of other field crops. They must therefore consider alternative methods to increase profitability of rhubarb production to remain competitive, especially on sites where they have no access to forcing sheds.

Forcing rhubarb is physiologically achieved in several ways. A slightly warmer constant temperature promotes the crowns to break dormancy sooner, producing earlier growth than in the field. The almost complete lack of light stalls normal leaf development (leaf expansion and chlorophyll production) as the crown channels energy into elongating the petioles as they search for light. The absence of light also prevents chlorophyll from being formed so the petioles do not begin to produce green pigment. There is also much less development of the leaf blade and it is likely that more of the crown's energy reserves will be channelled into the elongating petiole rather than being invested in the developing leaf.

Growers would benefit significantly if field-grown crops could be forced as well as those in sheds. This may offer increased produce value whilst avoiding the additional costs of forced rhubarb production in sheds. Whilst complete forcing is unlikely to be achieved in the field, it is possible that some form of intermediate forcing could be carried out by the cultivation of crowns under plastic where the use of plastic coatings could enable light manipulation. The exclusion of light, or distortion of the red to far red light ratio (which plants use as a developmental signal) could be used to achieve greater elongation of petioles, giving greater stick length at harvest. Enriched proportions of blue or red light may also increase pigmentation in the petioles, giving a brighter red colour at harvest. Lastly, plastic use is likely to create a warmer microclimate, encouraging crowns to break dormancy earlier and achieve faster rates of growth, providing early harvests.

Modification of the light spectrum can be achieved through the use of photoselective plastics in the field. These are carefully formulated polyethylene covers which can be placed over the crop in low tunnels and selectively absorb or transmit different wavelengths to produce a spectrum that is either enriched or depleted in certain regions to influence plant morphology and growth responses of the crop. Of particular interest here is the distortion of the red to far red light ratio. Plants use the ratio between red and far red light to sense whether they are growing in shade or in full sun – plants growing in shade will elongate further and faster as they seek to outcompete surrounding plants and reach stronger light, giving longer stems and petioles than would be seen in the open sun. This is a similar effect to that seen in the elongated petioles harvested from forced plants, so it is possible that manipulation of the red to far red ratio could be used to produce petioles of a greater length.

Different species will respond to this treatment in different ways, while non-target effects such as microclimate modification can have further impact on the growth of the crop or other aspects such as disease development. The use of such an approach in rhubarb may allow field-grown crops to be manipulated so as to improve the value of the harvested petiole by producing a product that is intermediary between forced and field-grown rhubarb either in terms of harvest window or quality.

Using this novel approach, this project was established to test whether the use of photo-selective plastics could be used to increase the profitability of field grown rhubarb. The work set out to meet the following five objectives:

1. To develop and trial a functional prototype photo-selective film polytunnel for effective rhubarb field forcing.
2. To compare different forcing strategies for their effect in crop yield and post-harvest crown condition, whilst testing their relative economic benefits.
3. To quantify the effect of rhubarb field film-forcing in marketable stem characteristics, e.g. colour, texture, sugars.
4. To assess the effectiveness of photo-selective protection in controlling rhubarb pests and diseases.
5. To generate grower guidelines for the implementation of photo-selective plastic technology.

1.3 Summary of the project

Approach

A literature review identified target spectral modifications that could be of benefit in rhubarb, such as those likely to promote pigmentation of petiole elongation. These were also linked with available commercial products that could be used to achieve these in a field setting. Two products were identified that enriched the blue and green portion of the spectrum by reducing red light transmission. It was considered that these had strong potential to achieve the desired effects on marketable product quality, particularly petiole elongation. Alongside the blue and green plastics, an opaque plastic was identified to replicate the commercial practice of field-forcing, whereby crowns are left in the ground but covered with light-excluding plastic in near-forcing conditions. As this plastic was available in two orientations (white out and black out), both forms were used separately to test whether the outer material had an impact on the achieved microclimate as a result of difference in absorbance/irradiance of heat. The two photo-selective plastics and two opaque plastics were to be compared against a clear plastic control which allowed high levels of light transmission to test whether any observed effects were due to light manipulation or due to changes in the microclimate alone. These five treatments were compared against field grown conventional green-pull rhubarb.

These plastics were used to skin small polytunnels over a 5-year old Timperley Early crop at Barfoots Farm, Romsey, Hampshire. At the end of February 2020, strong storm damage prevented earlier installation, but the tunnels were erected on 2nd March. Three tunnels each with a footprint of 1x4.8m were skinned with each plastic treatment, and were sealed at each end (**Figure i**). The crop was flailed before tunnel construction to ensure a consistent age between treatments and subject to standard pest/nutrient management approaches. The first harvest was taken on 18th March 2020, with subsequent pulls made on 26th March and 6th April. The first and second harvests were selective with only marketable petioles pulled, while the last harvest was entire. While it would have been beneficial to carry out later harvests, these were precluded by the onset of the covid-19 outbreak.

Figure i. Photograph of the trial area showing tunnels skinned with plastic treatments.

The petioles cut at each harvest were subject to a range of assessments. Gross and marketable yield after the discard of out of specification petioles (e.g. twisting, length) was recorded, along with the proportion of investment in the developing leaf. Petiole length, width and depth were recorded, along with the texture as indicated by a shore firmness meter. The colour of the petiole was mathematically determined at the top, middle and bottom points of a selection of petioles using a chromameter to quantify the strength of red or green pigmentation. These methods allowed for an appraisal of the quality produced from each treatment alongside bulk yield. The spectral qualities of the plastics were assessed before and after use to identify any degradation that might adversely affect the lifespan of new materials used in the field. These measurements were tailored to provide a holistic evidence base relating to the use of plastics in field rhubarb production.

1.4 Results

Marketable yield per crown was significantly reduced in the open field control relative to the plastic treatments – 423g/crown was seen in the open field control compared with 892 – 1,117g/crown in the plastic treatments (**Figure ii**). The bulk of the harvest was seen in the first harvest of the plastic treatments, while individual picks were relatively low between each harvest of the open field control. The blue and black plastic treatments gave the greatest marketable yield outputs (1,117g/crown and 1,088g/crown respectively) compared with the clear plastic which only achieved 892g/crown. Relative to gross yield, the plastic treatments achieved a much higher proportion of marketable yield (68 – 79%) than the open field control which achieved only 44% marketable yield.

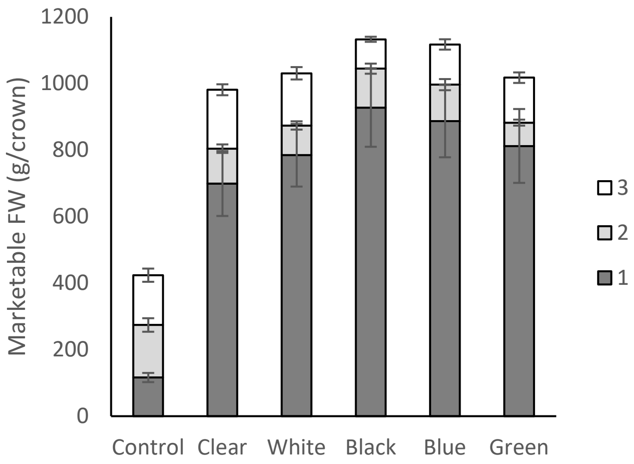

Figure ii. Marketable yield outputs for the first, second and third harvests, averaged per crown. Marketable yield from the control plots were significantly lower than those achieved in the plastic treatments, although there was no significant difference within the plastic treatments.

The limited duration of the trial has not allowed examination of the impact on yield across a complete season, but the use of plastics has significantly advanced the timing of harvestable yield compared with the open-field control. The uniform response between the clear, coloured and opaque plastics indicates that the early yield uplift is likely to be independent of light effects – most likely a warming of the microclimate increasing the rate at which crowns break dormancy and giving greater rates of growth.
However, significant differences were seen in the quality of petioles recovered from each treatment. Average petiole length in the petioles harvested from the black and white opaque plastics (34.3 and 35.23cm respectively) were significantly longer than those seen in the clear plastics and the open field control (29.2 and 28.6cm), while being significantly narrower (**Figure iii**). Petiole colour was also affected by the use of plastic treatments. The opaque plastics brought out the strongest pigmentation, giving deep red colour throughout the petiole. The other treatments showed partial greening, although this was limited only to the upper third of each petiole. The greening on the blue and green treatments was more significant than the clear and open-field control, but was limited to the upper third and did not lead to any loss of marketability (**Figure iv**)

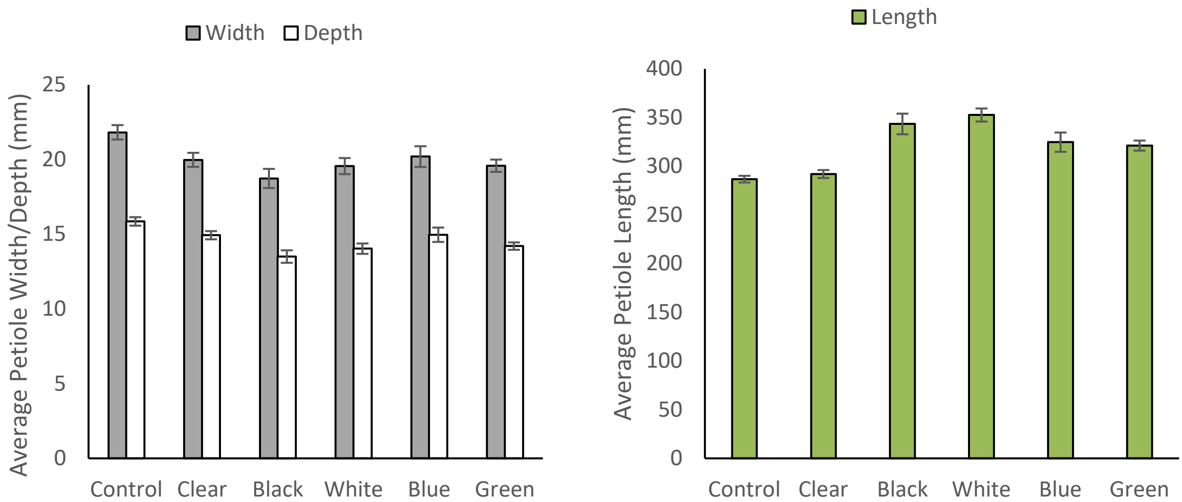

Figure iii. Average petiole length, width and depth as recorded across the trial.

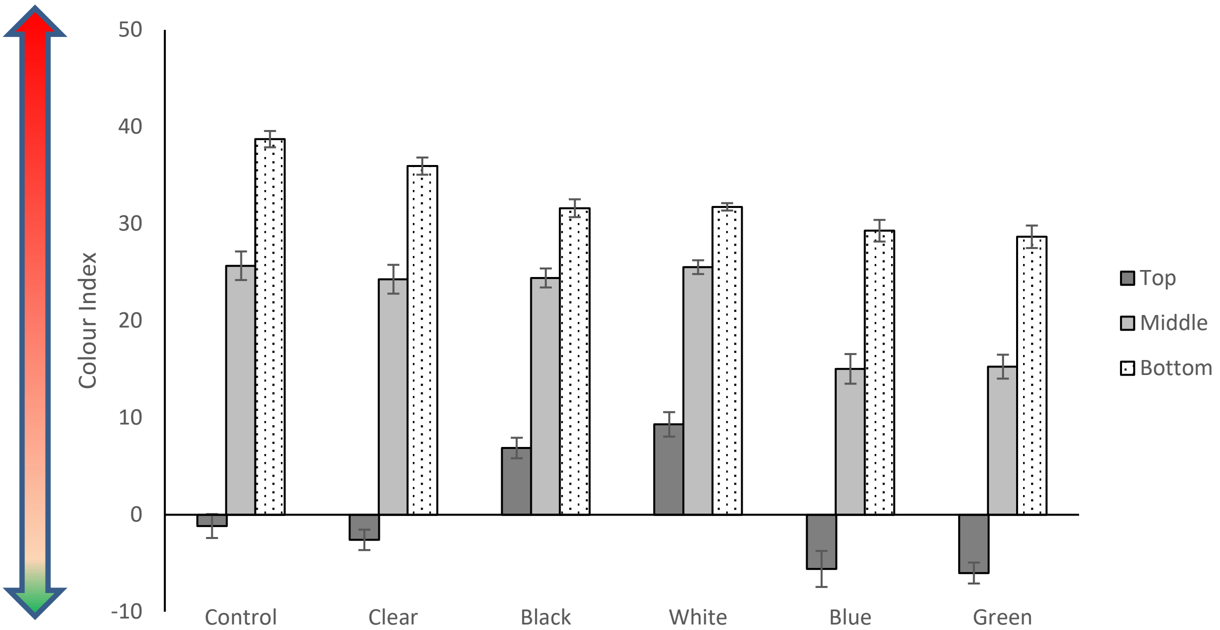

Figure iv. Petiole colour index measured at the top, middle and bottom petiole position. A more positive colour index indicates increasing red. Lower (or negative) colour index value indicates a stronger green colour.

Taken collectively, the use of plastics can be seen not only to advance early yields but also (in the case of blue, green and opaque plastics) increase the value of marketable quality. It is noteworthy that comparable effects on petiole length can be achieved with the opaque plastic treatment as the green and blue plastics. In opaque plastics, the elongated petioles are likely as a result of the crop growing in the search for light. In the blue/green plastics, a distortion of the red to far red ratio caused by the spectral modification is likely to be having a similar effect, leading to elongation of the petioles giving the increased length recorded here.

Within a single year of production, the ability of either plastic to give the quality benefits may lead to a plastic choice on price alone – the comparatively cheaper value of opaque plastic may promote its use over the green/blue plastics. However, the blue plastic allows for significant transmission of photosynthetically active radiation through to the crop, unlike the complete absence seen in the opaque treatments. The availability of light (whilst still achieving the desired uplift in quality and yield outputs) means that an additional resource is available to the crop – rather than relying solely on the reserves of the crown. The blue light enhanced treated petioles may be able to produce a significant quantity of sugars to support their growth – this is hypothetical at this stage but would be worth examining by tracking productivity of the treated crowns over several seasons. This may avoid exhausting the crown, promoting greater yields within a season or giving greater yields in the following season. While we have been unable to test this aspect in the current project, there is strong potential for this treatment to have longer-term benefits for growers seeking to increase the productivity of their crops in the early season.

The low yield of the open-field control is likely to be the result of the time at which harvests were taken rather than indicative of a reduced whole-season yield. Field production is normally in mid- to late spring, so the harvest window used in this trial is likely to have missed the main periods of productivity for open field production. As we have been unable to assess productivity over a complete season we are unable to fully explore the impacts of plastic on total yield output. However, we have been able to demonstrate that the use of plastics can significantly advance the timing of the harvest. The results of this trial indicate that around 15 tonnes/ha could be achieved with plastic use in March/April this year, compared with 6 tonnes/ha in the open field control. Assuming Timperley Early may yield around 44 tonnes/ha (based on Stockbridge House trials data), this means that plastic treatment could be used to achieve 34% of total yield in March compared with only 14% in open field plastic in the same period.

Main conclusions

- Rhubarb production in the UK is worth over £17m annually with high customer demand despite it being a niche crop. Rhubarb is a labour-intensive crop requiring harvesting by hand, and this has made rhubarb production difficult to automate. Growers must consider other routes to drive profitability of their production.
- Forced rhubarb grown in near-total darkness can achieve prices 6 times that of green pull rhubarb due to greater quality and earlier harvesting, although this carries greater labour costs from lifting and requires specific facilities whilst exhausting the crowns, preventing regrowth.
- Plastics which either block light completely, or modify the spectrum of light reaching the crop, are available as coverings for field rhubarb production. As light is responsible for the difference between forced and field grown rhubarb, this project examined whether plastic use could enhance the profitability of field grown rhubarb.
- Growing crowns under plastic in the field can address the gap between forced and green pull rhubarb. In this project plastic use increased marketable yield by 2.1 – 2.6 times that of open field harvested rhubarb in March, giving around 17 tonnes/ha compared with 6 tonnes/ha, assuming 15k crowns/ha.
- The work has shown that both opaque plastics and blue/green plastics can bring forward the harvest window for field-grown rhubarb by adjusting the quality of the light reaching the crop. Opaque plastics are likely to be around 20% cheaper to use, but blue plastic may allow the crops to produce some new sugars in the spring, lessening the exhaustive effect of early field-forcing.

1.5 Financial benefits

Based on the figures above, the use of plastic in open-field rhubarb production could bring forward roughly 20% of the total yield to the early part of the season. Based on trends in market value (**Figure 1 of the Science Section of this report**) there is a decline in wholesale rhubarb value of c. 30% between March and April. This means that produce harvested earlier will be of greater market value if harvested in March rather than later in the season. Assuming an initial value of £1/kg value to the grower, and that similar declines are seen later in the season, this would be equivalent to £9,000/ha in March compared with £6,300 in April. Plastic at a cost of 80p/m^2, alongside other costs such as tunnel hoops and labour inputs for construction would increase the cost of production (although the reuse of plastic over a 5-year period may reduce this). While the most cost efficient use of plastic may be achieved with opaque plastic, such treatment is liable to exhaust the crowns and reduce yield in subsequent years. However, the use of blue plastic may allow yield benefits (both in terms of productivity and quality) to be gained without exhausting the crowns as discussed above.

1.6 Summary

The use of plastics can drive productivity in field-grown rhubarb through a variety of ways. Light manipulation can positively affect quality of rhubarb achievable in the field. Opaque plastic offers longer sticks with greater pigmentation, while blue/green plastics offer long sticks without having as draining an effect on the crown, potentially increasing later harvests. Plastic use will also create a warmer microclimate around the crowns which can significantly advance harvests, making produce available earlier in the season.

While we have demonstrated that it is possible to increase the value of field-crown rhubarb it is considered that the likely costs and labour inputs required (particularly at a time when field access may be difficult) it is unlikely that large scale application of plastics would be seen. However, when applied on the small scale this may enable growers to bring forward a portion of their productivity to address the gap between forced and green-pull rhubarb, better enabling them to match customer demand whilst meeting greater market value early in the season.

1.7 Action points for growers

- Consider plastic coverings as a method for adjusting the period of productivity of field grown rhubarb. Both blue and opaque plastic may significantly bring forward the harvestable window for green-pull rhubarb, while offering significant enhancement of marketable qualities.
- Blue plastic use may offer greater benefits than opaque plastic between seasons by allowing the crop to generate new sugars for growth during the season rather than entirely relying on the crown for resources, whilst still producing petioles of improved quality.