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| **Project title:** | Effects of perennial weeds on weed control and fruit quality in blackcurrant |
| **Project number:** | SF 012 GSK229a |
| **Project leaders:** | Dr T Miller<br>Dr R Brennan, James Hutton Institute |
| **Report:** | Final Report, 2012 |
| **Previous report:** | None |
| **Key staff:** | T Miller (Washington State University),<br>D Jarret, R Brennan, and R Hancock (James Hutton Institute) |
| **Location of project:** | James Hutton Institute, Invergowrie, Dundee |
| **Industry Representative:** | Rob Saunders |
| **Date project commenced:** | 1 February 2012 |
| **Date project completed (or expected completion date):** | 31 December 2012 |

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

## *AUTHENTICATION*

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

Signature ..... Date

Signature ..... Date

**Report authorised by:**

Signature ..... Date

## *CONTENTS*

## *GROWER SUMMARY*

### Headline

- Broadleaf dock has a more deleterious effect on fruit quality, juice Brix and pH, anthocyanin content, sugar and vitamin C content than other weed species in blackcurrant.

### Background and expected deliverables

The number of herbicides approved for use in blackcurrants has diminished in recent years due to the EU review and harmonization of crop protection products. The recent loss of dichlobenil (Casoron) has had a significant effect on weed control in UK blackcurrant plantations and there has been a resulting increase in broad-leaved and perennial weeds. Docks (*Rumex* spp.), creeping thistle (*Cirsium arvense*), couch grass (*Elymus repens*) and mallows (*Malva sylvestris & M. neglecta*) are becoming particularly prominent.

Their presence in blackcurrant plantations can not only compete with the crop for light, water and nutrients, they can impede machine harvesting and contaminate the harvested crop. There is also concern that the yield and quality of fruit can be affected both by high levels of weed infestation and conversely, the use of traditional herbicide treatments. Since fruit quality is crucial to the juice processing industry, it is important to understand the impact of perennial weeds and herbicides on fruit quality.

This project aimed to provide clear information and a better understanding of how perennial weeds affect blackcurrant fruit yields and quality.

The objectives of the work were to:

1. Assess the impact of weed-infested plots on harvesting quality and fruit yield.
2. Correlate fruit quality factors, such as Vitamin C, sugars and organic acids with various treatments and an untreated crop.

## Summary of the project and main conclusions

Four species of perennial weeds at two different infestation densities were tested for their effect on berry yield and on resulting fruit quality in well-established blackcurrant during 2012. The trial was conducted at East Adamston Farm, Muirhead, Angus, Scotland courtesy of Andrew Husband.

Six-year-old blackcurrant ('Ben Hope') was used for the trial. Existing monotypic weed populations within three adjacent blackcurrant rows were identified for this trial on 23 May. The species were:

Broadleaf dock (*Rumex obtusifolius*);
Couch grass (*Elymus repens*);
Creeping thistle (*Cirsium arvense*);
Willow-herb (*Chamerion angustifolium*).

Infestations were rated as being "low" or "high" in density by species; plots were 1 m long, centered on a single row of blackcurrant bushes. Weeds were allowed to grow in the plots until most were in late bud stage, immediately before flowering of the first stems of creeping thistle and willow-herb, at which time weeds were clipped at the soil and above-ground fresh biomass was collected and weighed (26 July). Weed-free plots were kept free of all perennial weeds until harvest. All other weed species (both perennial and annual species) were removed by hand through berry harvest.

A range of quality parameters were measured at intervals following harvest including organic acid and sugar identification and quantification, vitamin C quantification, total fruit polyphenols and total anthocyanin.

The experimental design was a randomised complete block with four replicates. Only replicates 1 to 3 were picked for yield, while all four replicates were sampled for fruit quality analysis.

Full details of fruit quality sampling are included in the Science Section of this report.

Weed species alone did not affect berry yield or size. Juice yield was better when produced with broadleaf dock than with other weed species, although these berries were also more acidic and had lower ºBrix. Total polyphenol content was greater when berries were produced with creeping thistle than with either couch grass or willow-herb. Anthocyanin and sugar content

was greater when berries were produced with couch grass than with broadleaf dock or willow-herb. Vitamin C was content was better in fruit grown with couch grass or willow-herb rather than broadleaf dock.

Surprisingly, weed density did not play a major role in these results. Data were therefore combined across 'low' and 'high' density for these analyses. Several measured parameters were not closely related to weed density, but most parameters tended to be negatively affected by weed competition. Although not statistically significant ($P < 0.05$), berry yield and fruit size was numerically reduced by presence of weeds, while polyphenol, anthocyanin, sugar, organic acid, and vitamin C content were also reduced. Conversely, berry number and juice yield were non-significantly increased by weed competition.

When analysed, taking into account weed species and contrasting with blackcurrants grown in the absence of these perennial weeds, several patterns emerged in the data. Again, berry yield was not affected by the combination effect of weed species and density.

Weed biomass was slightly biased toward willowherb (2.02 kg/$m^2$) and away from couch grass (1.03 kg/$m^2$), showing that willowherb was more productive in competition with blackcurrant than couch grass.

Broadleaf dock reduced ºBrix and pH of blackcurrant fruit, the only weed species to do so in this analysis. Vitamin C content of fruit competing with broadleaf dock was reduced in comparison to fruit from non-weedy blackcurrant, although creeping thistle and, to a lesser extent, couch grass also reduced fruit content of vitamin C. Total polyphenol content was reduced by competition with willow-herb.

Full details of all the data collected from the quality sampling are included in the Science Section of this report.

### *Main conclusions*

- Weed density was not a major factor in either yield or fruit quality, although the trend in the data was for negative consequences resulting from weed competition.

- Of the four perennial weed species tested, broadleaf dock caused the most negative effects in fruit quality, lowering juice ºBrix and pH, and lowering anthocyanin, sugar, and vitamin C content compared to other weed species.

- Willowherb reduced polyphenol, anthocyanin, and sugar content, while couchgrass also reduced polyphenol and sugar content.

- Based on these single-year data, it appears that broadleaf dock should be the primary target for weed control efforts.

## Financial benefits

Given the results of this one-year project, it is difficult to calculate the exact financial benefits of weed control in blackcurrant plantations. However, given that plantation establishment costs amount to £4,000 per hectare and plantations can take up to three years to reach full production, any delay in reaching full production, which might be caused by weed competition, will result in lost revenue in the early life of a plantation and increase the time taken to pay off the establishment costs. This work has also demonstrated that certain weed species can have a deleterious effect on fruit quality, which could have an influence on the suitability of the harvested product for its intended market, such as juice.

## Actions points for growers

- Growers should aim to gain control of weeds during the establishment of blackcurrant plantations to achieve maximum yields as early in the crop life as possible.

- Particular attention should be paid to perennial weed control and especially broad-leaved dock, which can have a deleterious effect on a range of fruit quality parameters.

## *SCIENCE SECTION*

## Introduction

Perennial weeds are an increasing problem in soft fruit production worldwide. Control of them is usually challenging and results are not fully satisfactory. In Europe, herbicide availability is decreasing due to the implementation of new regulations: for example, the most effective product providing season-long weed control, Casoron (dichlobenil), was recently withdrawn. It is certain that there will be similar withdrawals in years to come, and it is therefore timely for UK fruit growers to seek alternative products and methods to improve control of perennial weeds in their plantations.

Blackcurrant plantations are especially vulnerable to perennial weed infestations due to the long-establishment of most plantations. There has been a significant increase in broad-leaved biennial and perennial weed growth in blackcurrant fields across the UK this year (2011), especially dock (*Rumex* spp.), creeping thistle (*Cirsium arvense*), couch grass (*Elytrigia repens*) and mallows (*Malva sylvestris & M.neglecta*). Weeds such as these impact negatively on plant growth, mainly due to resource competition, and can impede machine harvesting. Furthermore, there is concern among fruit processors and growers that the yield and quality of fruit can be affected by both certain herbicide treatments and conversely by high levels of weed infestation. Since fruit quality is crucial to the juice processing industry, it is important to understand the impact of perennial weeds and herbicides on fruit quality.

It can therefore be seen that there is an urgent need for research outlining methods and products that could be utilised in crop protection programmes to support UK blackcurrant growers in perennial weed control.

### *Aim and objectives*

This work aimed to provide clear information and a better understanding of how perennial weeds affect blackcurrant fruit yields and quality.

The objectives of the study were to:

1. Assess the impact of weed-infested plots on harvesting quality and fruit yield;
2. Correlate of fruit quality factors, such as Vitamin C, sugars and organic acids with various treatments and in untreated crop.

## Materials and methods

Four species of perennial weeds at two different infestation densities were tested for their effect on berry yield and on resulting fruit quality in well-established blackcurrant during 2012. The trial was conducted at East Adamston Farm, Muirhead, Angus, Scotland courtesy of Andrew Husband.

Six-year-old blackcurrant ('Ben Hope') was used for the trial. Existing monotypic weed populations within three adjacent blackcurrant rows were identified for this trial on 23 May. The species were:

Broadleaf dock (*Rumex obtusifolius*);
Couch grass (*Elymus repens*);
Creeping thistle (*Cirsium arvense*);
Willow-herb (*Chamerion angustifolium*) (Figure 1).

**Fig. 1a** Couch grass

**Fig. 1b.** Creeping thistle

**Fig. 1c**. Willow-herb

Infestations were rated as being "low" or "high" in density by species; plots were 1 m long, centered on a single row of blackcurrant bushes. Weeds were allowed to grow in the plots until most were in late bud stage, immediately before flowering of the first stems of creeping thistle and willow-herb, at which time weeds were clipped at the soil and above-ground fresh biomass was collected and weighed (26 July). Weed-free plots were kept free of all perennial weeds until harvest. All other weed species (both perennial and annual species) were removed by hand through berry harvest.

Plots were harvested by hand on 31 July, 2 August, and 6 August (replications 1, 2 and 3, respectively) and berries were weighed in the field. Additionally, 50-ml berry samples were collected from each plot and frozen at -80 C until used for fruit quality analyses.

Three-berry subsamples were extracted for organic acid and sugar identification and quantification on 16-20 August and for vitamin C quantification on 27-28 September (Fig. 2). Total fruit polyphenols were measured on 7 September and total anthocyanin on 18 September using a spectrophotometer.

Sugars were identified and quantified on 29-30 August and organic acids were identified and quantified on 12-14 September, both using HPLC (Fig. 3). Fruit remaining following extraction were processed for juice ºBrix score and pH on 26-27 September.

The experimental design was a randomized complete block with four replicates. Only replicates 1 through 3 were picked for yield, while all four replicates were sampled for fruit quality analysis. Data were analyzed using SAS, and means were separated using Fisher's Protected LSD (P = 0.05).

**Fig 2.** Fruit extract samples for HPLC analysis

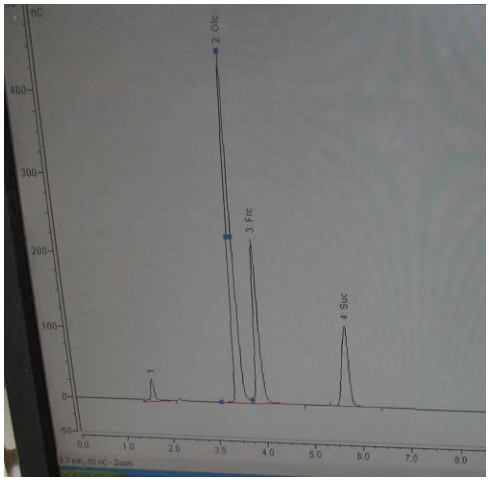


**Fig 3.** HPLC chromatogram for sugars

## Results and discussion

Weed species alone did not affect berry yield or size (Table 1). Juice yield was better when produced with broadleaf dock than with other weed species, although these berries were also more acidic and had lower ºBrix. Total polyphenol content was greater when berries were produced with creeping thistle than with either couch grass or willow-herb. Anthocyanin and sugar content was greater when berries were produced with couch grass than with broadleaf dock or willow-herb. Vitamin C was content was better in fruit grown with couch grass or willow-herb rather than broadleaf dock.

Surprisingly, weed density did not play a major role in these results (Table 2). Data were therefore combined across "low" and "high" density for these analyses. Several measured parameters were not closely related to weed density, but most parameters tended to be negatively affected by weed competition. Although not statistically significant ($P < 0.05$), berry yield and fruit size was numerically reduced by presence of weeds, while polyphenol, anthocyanin, sugar, organic acid, and vitamin C content were also reduced. Conversely, berry number and juice yield were non-significantly increased by weed competition.

When analyzed, taking into account weed species and contrasting with blackcurrants grown in the absence of these perennial weeds, several patterns emerged in the data (Table 3). Again, berry yield was not affected by the combination effect of weed species and density.

Weed biomass was slightly biased toward willow-herb (2.02 kg/$m^2$) and away from couch grass (1.03 kg/$m^2$), showing that that willow-herb was more productive in competition with blackcurrant than couch grass.

Broadleaf dock reduced ºBrix and pH of blackcurrant fruit, the only weed species to do so in this analysis. Vitamin C content of fruit competing with broadleaf dock was reduced in comparison to fruit from non-weedy blackcurrant, although creeping thistle and, to a lesser extent, couch grass also reduced fruit content of vitamin C. Total polyphenol content was reduced by competition with willow-herb.

## Conclusions

- Weed density was not a major factor in either yield or fruit quality, although the trend in the data was for negative consequences resulting from weed competition.
- Of the four perennial weed species tested, broadleaf dock caused the most negative effects in fruit quality, lowering juice ºBrix and pH, and lowering anthocyanin, sugar, and vitamin C content compared to other weed species.
- Willow-herb reduced polyphenol, anthocyanin, and sugar content, while couchgrass also reduced polyphenol and sugar content.
- Based on these single-year data, it appears that broadleaf dock should be the primary target for weed control efforts.

**Table 1.** Weed biomass, berry yield, and fruit quality parameters of 'Ben Hope' blackcurrant after season-long competition with four perennial weed species (2012).

| Treatment[z] | Weed biomass | Berry yield | Berry number | Mean berry weight | ºBrix | pH | Juice yield | Total polyphenols | Total anthocyanin | Total sugars | Total organic acids | Vitamin C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | kg/m$^2$ | kg/m$^2$ | no./sample | g/berry | | | L/tonne | mg/100ml | mg/500ml | g/L | g/500ml | mg/100ml |
| **Broadleaf dock** | 0.82 | 2.08 | 21.8 | 1.00 | 14.2 b | 2.56 b | 534 a | 3444 ab | 2005 bc | 340 b | 57 | 0.58 b |
| **Creeping thistle** | 1.00 | 2.07 | 20.2 | 1.05 | 15.1 a | 2.62 a | 486 b | 3991 a | 2491 ab | 436 a | 78 | 0.73 ab |
| **Couchgrass** | 0.69 | 1.83 | 20.3 | 0.99 | 15.7 a | 2.62 a | 475 b | 3355 b | 2607 a | 430 a | 74 | 0.86 a |
| **Willow-herb** | 1.35 | 2.14 | 20.0 | 0.99 | 15.3 a | 2.60 ab | 483 b | 2868 b | 1629 c | 313 b | 53 | 0.92 a |
| **Pr > F** | 0.60 | 0.64 | 0.47 | 0.88 | 0.0008 | 0.03 | 0.003 | 0.01 | 0.003 | 0.002 | 0.14 | 0.02 |

Means within a column and followed by the same letter, or not followed by a letter, are not significantly different (P < 0.05).
[z]Weeds removed 26 July 2012; berries harvested 31 July-6 August 2012.

**Table 2**. Weed biomass, berry yield, and fruit quality parameters of 'Ben Hope' blackcurrant after season-long competition with or absence of weeds (2012).

| Treatment[z] | Weed biomass | Berry yield | Berry number | Mean berry weight | ºBrix | pH | Juice yield | Total polyphenols | Total anthocyanin | Total sugars | Total organic acids | Vitamin C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | kg/m$^2$ | kg/m$^2$ | No./sample | g/berry | | | L/tonne | mg/100ml | mg/500ml | g/L | g/500ml | mg/100ml |
| **No weeds** | 0 b | 2.17 | 20.1 | 1.04 | 15.1 | 2.60 | 485 | 3645 | 2273 | 399 | 67 | 0.80 |
| **Weedy** | 1.46 a | 1.96 | 20.9 | 0.99 | 15.1 | 2.60 | 500 | 3277 | 2127 | 368 | 65 | 0.76 |
| **Pr > F** | <0.0001 | 0.29 | 0.47 | 0.31 | 0.88 | 0.79 | 0.28 | 0.12 | 0.51 | 0.24 | 0.84 | 0.59 |

Means within a column and followed by the same letter, or not followed by a letter, are not significantly different (P < 0.05).
[z]Weeds removed 26 July 2012; berries harvested 31 July-6 August 2012.

**Table 3.** Weed biomass, berry yield, and fruit quality parameters of 'Ben Hope' blackcurrant after season-long competition with four perennial weed species (2012).

| Treatment[z] | Weed biomass | Berry yield | Berry number | Mean berry weight | ºBrix | pH | Juice yield | Total polyphenols | Total anthocyanin | Total sugars | Total organic acids | Vitamin C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $kg/m^2$ | $kg/m^2$ | no./sample | g/berry | | | L/tonne | mg/100ml | mg/500ml | g/L | g/500ml | mg/100ml |
| **Broadleaf dock** | 1.23 ab | 2.10 | 21.5 | 0.99 | 14.2 c | 2.55 b | 529 | 3448 a | 2149 | 346 | 58 | 0.56 c |
| **Creeping thistle** | 1.57 ab | 1.82 | 20.6 | 1.09 | 15.1 b | 2.61 a | 503 | 3827 a | 2483 | 415 | 77 | 0.71 bc |
| **Couchgrass** | 1.03 b | 1.66 | 21.3 | 0.93 | 15.9 a | 2.62 a | 467 | 3214 ab | 2326 | 419 | 74 | 0.80 abc |
| **Willow-herb** | 2.02 a | 2.27 | 20.1 | 0.99 | 15.2 ab | 2.60 a | 500 | 2686 b | 1594 | 297 | 51 | 0.96 a |
| **No weeds** | 0 c | 2.17 | 20.1 | 1.04 | 15.1 b | 2.60 a | 485 | 3645 a | 2273 | 399 | 67 | 0.80 ab |
| **Pr > F** | < 0.0001 | 0.23 | 0.87 | 0.22 | 0.002 | 0.02 | 0.12 | 0.02 | 0.23 | 0.08 | 0.08 | 0.04 |

Means within a column and followed by the same letter, or not followed by a letter, are not significantly different ($P < 0.05$).
[z]Weeds removed 26 July 2012; berries harvested 31 July-6 August 2012.