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Management of clubroot (*Plasmodiophora brassicae*) in winter oilseed rape

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1. ABSTRACT

Clubroot is an increasing problem in oilseed rape crops throughout the UK and has been exacerbated by close rotations, as the disease can persist for upwards of 15 years in soils. The galls on roots formed by the clubroot pathogen, *Plasmodiophora brassicae*, affect normal root function and reduce the uptake of water and nutrients such that even low levels can reduce yield. Root galls will commonly breakdown with secondary rots such that root function is seriously impaired.

Yield losses to clubroot in this project were 0.3 t/ha for every 10% clubroot severity. Losses in affected crops can therefore equate to over 50% of potential yield in the most severely infected crops. Survey work in this project, for the years 2007-2009 showed that the disease was present in all areas of the UK where oilseed rape was grown. Of the sites surveyed, 52% tested positive. The sites sampled were not randomly selected and growers and agronomists who participated tended to select fields of concern. These positive test results were often at sub clinical levels in the crop.

An aim of the project was to investigate the use of varietal resistance and /or soil amendments, Calcium carbonate (LimeX70), Calcium cyanamide (Perlka) and boron (Solubor) to manage clubroot in affected fields. Soil amendments gave variable control but showed some potential as part of a clubroot management strategy. Varietal resistance remained the more effective management tool for growers, but varietal resistance is under pressure at sites where it has been heavily used in back rotations and varietal control was not effective at sites in Aberdeenshire. The varieties Mendel and Cracker, gave 50 – 95% disease control at three sites in the West Midlands. Control with soil amendments ranged from 0 – 90% but analysed over the trial series control meaned at 25% for the best solo treatment (Calcium carbonate at 8 t/ha). The Calcium cyanamide product is no longer supported for use on oilseed rape crops in the autumn in the UK. Soil testing for clubroot and soil pH, and lengthening rotations are important to the long term management of clubroot on farms, as varietal resistance and soil amendments give inconsistent results.

2. SUMMARY

Clubroot is an increasing problem in oilseed rape crops throughout the UK and has been exacerbated by close rotations. The disease can persist in soils for upwards of 15 years and has a half-life of 3.7 years so that in relatively short three or four year rotations it builds in severity in affected fields. The galls on roots formed by the clubroot pathogen affect normal root function and reduce the uptake of water and nutrients such that even low levels can reduce yield. Root galls will commonly breakdown with secondary rots such that root function is seriously impaired and yield in affected crops can be reduced to less than half of potential yield. A series of warm and wet autumns prior to the start of this project also exacerbated symptoms in oilseed rape crops and it was a common advisory problem in diagnostic clinics, but the extent of the problem was unknown.

The disease affects a wide host range and is very problematic in brassica vegetable production. In the vegetable scenario land is commonly rented for production and clubroot is typically managed by soil testing prior to cropping and then rejecting heavily infested fields. Clean land is a diminishing resource and for oilseed rape cropping on affected farms, avoiding infected fields is seldom an option. Disease severity is linked to soil acidity and available calcium content and work on vegetables has shown that soil amendments which can raise these parameters can significantly reduce clubroot infection and maintain yields. Clubroot has thick-walled resting spores which are very resistant to both environmental stress and to soil treatments, hence their ability to persist in soil for very long periods. In order to infect, these resting spores germinate into motile zoospores that can swim towards, and infect the roots of host plants. It is at this stage that they are most vulnerable to treatments or to hostile soil conditions and previous work on vegetable crops has demonstrated that if a spike in pH and calcium can coincide with early infection, soil amendment treatments are likely to be most effective. This is easier to achieve with transplanted brassica crops where the root exudates stimulate the clubroot spores to germinate and soil treatment is closely timed to planting. Treatments with greatest efficacy in vegetable crops in previous work were very fine forms of lime where the pH and calcium availability rise in soils was rapid. Limex70 (a Calcium carbonate by-product of the sugar beet industry) and Perlka (a calcium cyanamide product) are widely used on vegetable crops in this context but their efficacy on oilseed rape was unknown.

The current project aimed to investigate management of clubroot in oilseed rape, with five specific sub aims. The first was to determine through survey work the extent of the problem in UK crops. The second was to test varieties for disease resistance or tolerance and determine the potential of varietal resistance as a management tool. The third objective was to investigate the efficacy of soil amendments in field trials. The fourth objective was to determine if future climate change scenarios would increase or decrease clubroot severity and the final objective was to develop a quantitative real-time PCR diagnostic assay for the disease.

Survey work in this project, for the years 2007 – 2009, revealed that 52% of sampled oilseed rape fields were infected with clubroot when tested in bioassays of the soil. Scottish sites sampled had a 50% infection rate and English samples 54%. Samples size was 96 sites. Sites were not randomly selected and the agronomists and growers who participated tended to select fields of concern (because of intensive rotation or because they had seen patches of poor growth). The actual incidence of infection therefore is probably somewhat lower than this but nevertheless these figures are representative of infection levels on intensive holdings. These positive test results were often at very low levels of severity in the bioassay test and were therefore still at sub clinical levels in oilseed rape and not yet problematic or observable in the affected fields surveyed. This indicates that the problem will build in severity in future crops, and increase in importance to the industry. Where fields were sampled and assessed in subsequent years within this project the decline in clubroot noted between seasons was minimal, which is indicative of its longevity within the soil. The declines noted were in line with those observed in previous literature with a half-life of around 3.5 - 4 years.

Maps of the distribution of affected fields in the UK were produced which showed 'hot spots' of infection relating to areas of intensive brassica or oilseed rape production. The disease was noted in all areas tested, but was more prevalent in relation to the acreage of crop grown in the north east of Scotland. This is indicative of the short rotations of oilseed rape in this area and the lack of alternative reliable break crops for cereals at this latitude. Soils sampled in the course of the survey were also tested for pH and extractable calcium content but there was no correlation between these parameters and disease severity in the survey. Disease severity was more influenced by previous field history, and high levels were noted at Aberdeen sites with rotations of one in two, with winter barley as the intervening crop.

The progress of a clubroot epidemic within a season is dependent on weather and in particular is favoured by wet and warm autumn conditions. Infection ceases below soil temperatures of 8^{o}C. Using climate change modelling and weather predictions for the 2020 and 2050 timeframes (using data from the A1B Global Climate Model), maps of future clubroot risk were produced using the CLIMEX^{TM} computer simulation programme. The modelling indicated that the pathogen can survive in a wide range of conditions and will be reasonably resilient to drought. It will benefit from predicted higher temperatures which will extend its growing season and allow for more generations in some regions so that, by 2050, larger areas of the UK than currently will become suitable for clubroot. This picture will worsen if crops are irrigated.

Using a bioassay, varieties were screened for tolerance to clubroot in the hope that this would offer a sustainable strategy for growers. The bioassay included Mendel which carries a known resistance to clubroot. This was the only variety where a significant reduction in clubroot was

noted. What was of concern, however, was that a high level of infection was still noted in the Mendel (an index of 26.9% compared to a mean of 74.1 for the susceptible varieties). The soil used in the bioassay was taken from a site in Fife with a back history of using Mendel. Little is known or understood about clubroot populations but variable host pathogenicity is known. It has been observed that the Mendel resistance is eroded at sites where it is commonly used and it is likely that strains of clubroot that can overcome this resistance mechanism build up in this scenario. Susceptible volunteers in the field can be one explanation of clubroot infection in fields of Mendel, however the bioassay results, in controlled conditions and with certified seed, confirms that strains of clubroot exist that can overcome this host resistance.

The variety Cracker was introduced to the market midway through this project and was evaluated in the field trials described below. Although Cracker has better foliar disease ratings and improved agronomic characterises and yield, it carries the same resistance mechanism as Mendel and is not therefore an alternative strategy in managing clubroot at sites where Mendel has previously been used.

Clubroot is favoured by acid soils and liming has been a common strategy in reducing disease severity. Previous work on vegetable brassicas demonstrated the potential of different sources of lime and indicated that finely ground and more available types were more effective. Products that raise soil calcium are also successfully applied to vegetable brassica crops to reduce clubroot infection, for example Calcium cyanamide. Boron is another soil amendment used in the vegetable scenario.

An aim of the project was to investigate the use of soil amendments and varietal resistance to manage the problem. Six field trials were carried out in the three seasons of this project, 2007-2008, 2008-2009 and 2009-2010. Two sites were established per season, one in Aberdeenshire and one in the West Midlands. The clubroot epidemics observed at the sites varied hugely, even between two sites in the same season. In some trials clubroot was severe from early autumn, throughout the whole season, at others it was low in the autumn but increased to moderate levels in the following spring and at some it was low throughout the season. Soil amendments were therefore evaluated in a wide range of disease scenarios. Calcium cyanamide (Perlka), Calcium carbonate (LimeX70) and boron (Solubor) were evaluated. Treatments were adjusted over the course of the trial series such that only the most effective treatments were continued, and in the later years attention was given to combined treatments. The susceptible variety Kommando was used throughout, as was the resistant variety Mendel. The variety Cracker was trialled in the final season only, as a coded variety prior to its launch on the UK market.

Results showed that both soil amendments and varietal resistance gave variable control but that varietal resistance remained the more effective management tool for growers at sites where it had not already been deployed.

In six trials over three seasons, varietal resistance as found in Mendel and Cracker gave 65- 99% disease control at three sites in the West Midlands (Warwickshire, Shropshire and Hereford). Varietal control was not evident at the three Aberdeen sites where Mendel had been commonly used prior to the trial series. Yield benefits varied. Mendel yielded significantly better than Kommando at the 2007-2008 Shropshire trial site where disease severity was high but did not improve yield the following year at a Hereford site where disease severity was lower. This is indicative of the lower yield potential of Mendel, which is now somewhat outclassed agronomically. At a Warwickshire site in the final year of trials the varieties Mendel and Cracker did give significant yield improvements in a similar disease epidemic. Mean yields averaged over all treatments were 4.12 t/ha for Kommando, 4.52 t/ha for Mendel and 4.53 t/ha for Cracker.

Clubroot control was also highly variable with soil amendments. Analysis over the whole trial series demonstrated potential disease control of around 25% with Calcium carbonate at 8 t/ha, but control ranged from 0% control to over 95% control at different sites. Control was not noted with solo field amendments at the three Aberdeen sites, although a combined Calcium carbonate, Calcium cyanamide and boron treatment did give control in the latter year of trialling, but did not raise yield significantly. The calcium cyanamide product trialled did reduce clubroot severity (but did not significantly increase yield) at the Warwickshire site in 2009/2010 and at the preceding season's Herefordshire site, but the rate used (250 kg/ha) equates to an additional 50 kg of nitrogen applied and this exceeds the nitrogen limits that can legally be applied to oilseed rape crops in the autumn in the UK, so the product is no longer promoted for use on oilseed rape. This might be reviewed in 2013, and banded applications are being investigated by the manufacturer.

Yield benefits in response to soil amendment treatments were noted in two trials out of the six. Calcium carbonate at 8 t/ha raised yield by over a tonne per ha in the final year of trialling at a site in Warwickshire where disease intensity was low in the autumn and moderate in the spring. Similar treatments performed poorly at sites where disease intensity was either very low, so that differences were not significant, or very high where treatments were overwhelmed. Note that phytophthora root rot also contributed to plant losses at some sites, notably Shropshire in 2008. Analysis of the whole trial series did show significant yield benefits with predicted mean increases of 5% for Calcium carbonate and up to 20% for combined three way treatments with calcium carbonate+ calcium cyanamide + boron.

There were significant correlations between soil calcium content and diseases severity and also between soil pH and disease severity. There was no evidence in the data of any additive effect between the two.

A new, quantitative molecular test was developed. This was highly sensitive to clubroot infection in plants where it correlated well with disease severity and was more sensitive than existing tests. Interference issues with different soil types could not be resolved however, preventing its use for routine soil testing. This is thought to relate to the presence of inhibitors to the DNA amplification process in different soils types and soil results were inconsistent and related poorly to bioassay or observed field infections. A bioassay, or a shortened bioassay quantified by PCR testing on the plants therefore remains more accurate for growers who wish to test soils.

Of the management strategies available to growers, both varietal control and soil amendments were variable in their success and this demonstrates that soil testing for clubroot and lengthening rotations are important to the long term clubroot management strategy on farms. This should be combined with routine testing for soil pH as literature shows acidity will increase disease build up. Many of the fields tested in the course of this project were positive for clubroot but at levels not yet problematic to the crop. The disease severity in such fields is likely to become worse in subsequent years, making this issue more problematic. In addition, climate change modelling indicated that the pathogen can survive in a wide range of conditions and will be reasonably resilient to drought. It will also benefit from predicted higher temperatures and maps produced for the project show that by 2050 larger areas of the UK than currently will become suitable for clubroot. This picture will worsen if crops are irrigated.