INTERIM
PROJECT REPORT
for
FV 226a

To:

Horticultural Development Council
Bradbourne House
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Red Beet : Further Elucidation of the Cause, Epidemiology and Control of Root Malformation Disorder (RMD)

January 2004

Grower Summary

FV 226b

Red Beet: Further Elucidation of the Cause, Epidemiology and Control of Root Malformation Disorder (RMD)

Interim Report : January 2004

Project Title:	Red Beet: Further Elucidation of the Cause, Epidemiology and Control of Root Malformation Disorder (RMD)
Project Number:	FV 226b
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Project Co-ordinator:	Mr G Smith R Smith & Sons South Carr Farm Westwoodside Doncaster DN9 2EW
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The results and conclusions in this report are based on a series of field trials on commercial crops of red beet. The conditions under which the experiments were carried out and the results generated have been reported with detail and 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 to be used as the basis for commercial product recommendations.

It should also be noted that many of the products tested in this work are experimental in nature and under no circumstances should they be used commercially. If anyone is in doubt regarding the current approval status of a particular product they should either consult the manufacturer, check the status on an approved pesticide database or take independent advice from a BASIS qualified adviser.

AUTHENTICATION

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

Signature……………………………………………………………………………

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Project Manager
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Date…………………………

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GROWER SUMMARY

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FV 226b : GROWER SUMMARY

Red Beet : Further Elucidation of the Cause, Epidemiology and Control of Root Malformation Disorder (RMD)

Headlines

- Two complex replicated field trials were undertaken successfully during 2003, with the aid of enthusiastic grower and other stakeholder support.
- Levels of root malformation disorder (RMD) in commercial red beet crops during 2003 were low though occasional, mostly later drilled, crops did succumb to RMD levels of around 10-20%.
- Downy mildew occurred relatively early in several crops in the Isle of Axholme region of South Yorkshire. However, the dry weather conditions from mid-June onwards prevented epidemic development, though the disease could be found sporadically in most crops.
- *Rhizoctonia, Pythium* spp. and other potential pathogens were not generally evident in trial or other commercial crops during routine monitoring over the season though *Aphanomyces cochlioides* caused a significant level of damping-off in the trial site at Westwoodside. Soil sterilisation reduced the level of pre-and post-emergence damping-off considerably.
- The low incidence of RMD during 2003 can possibly be attributed to the unusually hot dry summer. However, fungicides were also used very widely in high risk areas and this may also have had some impact on the incidence of the disorder during 2003.
- In one of the two trial sites selected for study during 2003 levels of RMD were insignificant and only limited data was gathered during the season.
- At the second site, RMD did occur at low-moderate levels though was somewhat variable in its distribution and this will make analysis and interpretation of the data generated difficult.
- A strong correlation between the presence of downy mildew, the occurrence of a brown petiole symptom in plants and root malformation was found in some commercial crops and in the trial at Site 2. However, it should also be noted that it is not uncommon to find RMD affected plants with no visible expression of d. mildew infection and and downy mildew infected plants without RMD symptoms. Therefore it is not possible at this stage to confirm whether there is a definite link between RMD and the downy mildew infection observed in crops in recent years. However, in the absence of other potential causes this remains a strong possibility due primarily to the reported latency & symptomless nature of the pathogen in some crops and this remains a high priority to resolve.
- At Site 1 (Westwoodside) there was a very strong correlation between crop vigour at the end of the season and the applied fungicides. This was attributed to the control of foliar disease, primarily rust (*Uromyces betae*), at this site with Amistar proving to be the most effective product. The dithiocarbamate (mancozeb) component of Fubol Gold and Invader also proved surprisingly

effective. Bavistin gave a moderate suppression of the disease, whereas SL567A, Basilex and Biomex/Vitomex were ineffective.

- At Site 2 (West Butterwick) there was also a differential effect on plot vigour at harvest though here there appeared to be no correlation with the applied treatments.
- An extensive literature search has indicated that the downy mildew (*P. farinosa* f. sp. *chenopodii*) on Chenopodiaceous weeds such as 'fat-hen' (*Chenopodium album*), is different to that (*P. farinosa* f. sp. *spinaciae*) which occurs on Spinach (*Spinacia oleracea*) and this in turn is different to that (*P. farinosa* f. sp. *betae*) which occurs on commercial red beet or sugar beet (*Beta vulgaris*). Cross-inoculation studies between the different host-pathogen combinations, as reported in the scientific literature, have proved negative and therefore it must be concluded that the downy mildew inoculum pressure from 'fat-hen' or related weeds presents no infection risk to the red beet crop. However, any infection in commercial sugar-beet crops is likely to provide inoculum for potential cross-infection to red beet crops in the vicinity.
- In parallel with this trials work, significant progress has been made in securing fungicide use on the crop and SOLAs for Wakil XL (metalaxyl/fludioxinil/cymoxanil) seed treatment (SOLA No. 2313/03) and foliar sprays of Amistar (azoxystrobin : SOLA No. - 1126/03) and Filex/Proplant (propamocarb hydrochloride : SOLA No's - 1247/03 & 1453/03) were granted during 2003 for the control of RMD in red beet. It remains to be determined whether they are effective in this regard.
- It is proposed that the trials work is extended for another year to provide an additional opportunity to further evaluate control of RMD and to provide robust evidence for a link between specific plant pathogens and RMD.
- It is also recommended that a serological/PCR technique for *Peronospora farinosa* is developed to determine whether RMD affected crown/root tissues are systemically infected by this obligate pathogen. It is hoped that this approach would allow us to either eliminate the pathogen as the primary cause or confirm systemic infection in RMD affected roots.

Background and Expected Deliverables

During early Autumn 1998 concerns were raised by a no. of growers regarding the occurrence of an apparent new disorder or disease of red beet. As crops neared maturity roots were observed to be severely distorted (Plate 1).

Plate 1 : RMD affected beet in the field (right). Note proximity to adjacent healthy beet (left).

In addition to the distortion, affected roots had an elongated neck and, in some cases, had a thickened tap root. One particular characteristic of the affected beet was a russetting or corkiness around the shoulder of affected plants (Plate 2).

Plate 2 : Distorted roots of red beet with an elongated neck, russetting and corkiness around the shoulder.

The smaller or 'baby beet' size grades were reported to be particularly badly affected. The syndrome was referred to as root malformation disorder or RMD. Various estimates put economic losses due to RMD at around £1M/annum.

HDC sponsored a 2-year investigation at Stockbridge House during the period 1999-2001. Studies commenced on a broad basis in Year 1 to conduct a literature search, distribute a questionnaire to growers, conduct a series of pot studies and to eliminate a number of possible factors that could potentially have led to such severe root distortion. During this initial investigation, tests for 'Rhizomania' and other virus diseases were conducted, as were tests for herbicide injury, nematode infestation and bacterial pathogens. All tests proved negative.

In the second year of the project information gleaned from the pot studies were used to design and undertake a series of replicated field-scal~~e trial~~s on commercial farms to evaluate the performance of various experimental fungicides applied as seed treatments and post-emergent HV sprays. Results from this work were more variable than hoped due, in part, to the relatively low incidence of RMD during that period. However, individual sites did respond moderately well to fungicides and at site 2 (Westwoodside) RMD symptoms were well controlled with metalaxyl-M applied as SL567 (for oomycete control) either as a seed treatment or drench application. At the other 2 sites levels of RMD were much lower. Some response from the applied products, particularly SL567A, Monceren (for *R. solani* control) and Biomex (also targeting *R. solani* primarily) was achieved. Whilst it was considered that further investigation was required to fully elucidate the problem, preliminary discussions with a view to extending the work for a 3rd

year were not successful. Therefore, based on the 2-year study, it was concluded that the most probable cause for RMD was a *Pythium-Rhizoctonia* complex, infection occurring at the seedling stage with the distortion symptoms developing as the roots enlarged. A recommendation was therefore made to pursue On- or Off-Label authorisation for the fungicide metalaxyl-M (SL567) and possibly azoxystrobin (Amistar). Unfortunately though, for a variety of reasons, this recommendation was not pursued and fungicide authorisations were not immediately secured following submission of the final report.

In October 2002 growers, particularly in the Isle of Axholme region of South Yorkshire, again reported an extremely high incidence of RMD. On this occasion, it appeared that the problem developed quite late in the season (August-September). In some cases it was severe in fields that had not grown commercial crops in the Chenopodiaceae for several years or on land that had been down to grass for 20 years. As previously, the problem appeared to correlate closely with wet weather, in this case heavy rainfall during August after a prolonged dry spell. The reported absence of early symptoms and the presence of severe RMD in 'virgin' sites, rather than pointing to a soil-borne pathogen, tended to suggest aerial dissemination eg an aphid vectored virus or an air-borne fungus.

Close inspection of affected crops noted a fairly heavy infestation of downy mildew caused by *Peronospora farinosa* f. sp. *betae* (Plate 3), a pathogen not noted at particularly significant levels in previous years.

Plate 3 : Crown infection of red beet with downy mildew (*Peronospora farinosa* f.sp. *betae*).

As an oomycete this obligate pathogen could also be expected to be well controlled (subject to the absence of resistant strains in the pathogen population) by SL567A and can occur systemically to cause distortion, without obvious sporulation, in some crops. A web-based report from Oregon in the USA describes symptoms of d. mildew in red beet (Plate 4) that correlates closely with those of RMD and this certainly requires further investigation.

Plate 4 : Distorted roots of red beet, claimed to be caused by the downy mildew pathogen (Oregon, USA).

The aim of the extended project is to further investigate the role played by both soil- and air-borne pathogens in field-scale trials, including soil sterilisation treatment, to further elucidate the cause(s) of RMD and, if possible, to provide effective measures for control of the problem. The primary objective/deliverable was to undertake two large-scale, fully replicated, field trials on commercial nurseries to evaluate a range of existing and novel fungicides. Separately, a search of past scientific literature on the subject was to be conducted. The primary aim was to determine if there is any information available to ascertain whether the d. mildew pathogen found on wild *Chenopodiaceae* possibly acted as a reservoir for subsequent infection of commercial 'beet', or indeed whether different host-specific pathovars were involved here.

Summary of the Project and Main Conclusions to Date

(i) Progress of replicated trial sites with fungicide treatments

Following extensive discussion with industry representatives two sites for trial purposes were identified on commercial farms in South Yorkshire. At each site half the area was treated with the soil sterilant product metham sodium (Discovery) by Sands Agricultural Services Ltd during late April 2003. Red beet seed cultivars Darko (Site 1 – Westwoodside) & Crimson Globe (Site 2 – West Butterwick) were drilled in early May and a range of fungicide and related treatments applied on a replicated basis almost immediately (Table 1). All sprays were applied using purpose-designed tractor-mounted equipment. Spray treatments were applied at approximate 4 week intervals aiming to provide broad protection from drilling through to maturity. A diary of the various applications at each of the trial sites is presented in Table 2.

Table 1 : List of fungicides and related treatments applied to the two field trial sites during 2003

Product	Active Substance	Rate of application (product/ha)	Water volume (litres/ha)	No. & timing of applications
1. Untreated (water) control	-	-	500	5 at monthly intervals
2. SL567A + Amistar	Metalaxyl-M + azoxystrobin	0.22l + 1.0l#	500	5 at monthly intervals
3. SL567A	Metalaxyl-M	1.3l	500	1 post-drilling
4. SL567A	Metalaxyl-M	0.22l	500	5 at monthly intervals
5. Fubol Gold	Metalaxyl-M + mancozeb	1.9kg	500	5 at monthly intervals
6. Invader	Dimethomorph + mancozeb	2.0kg	500	5 at monthly intervals
7. Basilex	Tolclofos-methyl	5.0kg* & 3.0kg	500	5 at monthly intervals
8. Amistar	azoxystrobin	1.0l	500	5 at monthly intervals
9. Bavistin DF	carbendazim	1.1l	500	5 at monthly intervals
10. Biomex + Vitomex	*Trichoderma* spp. + phosphite	1.0l + 4.0l#	500	5 at monthly intervals

** 1st application only, all subsequent applications at the lower rate.*
 # tank-mix application

Table 2 : Diary of various actions undertaken at the two field trial sites during 2003

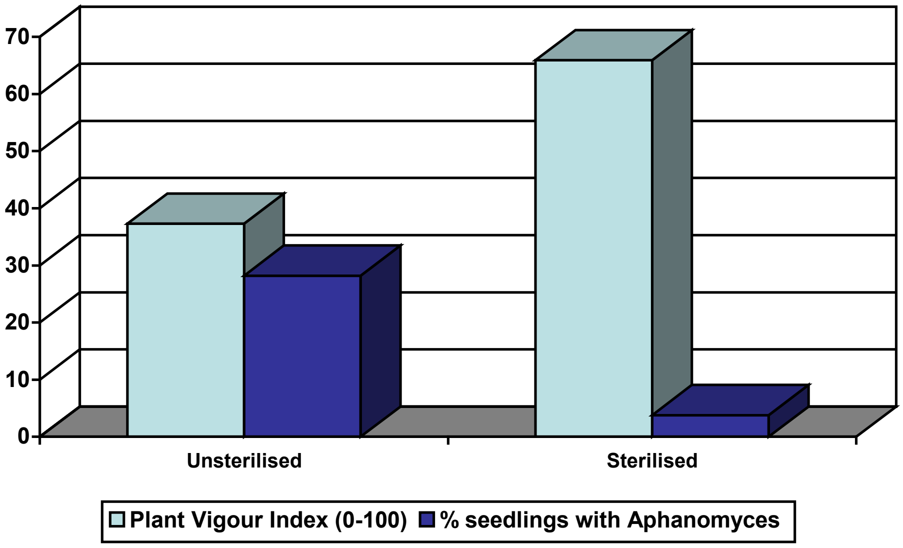
Action	Site 1 (Westwoodside)	Site 2 (West Butterwick)
Soil sterilisation treatment	April 2003	April 2003
Drilling date	6 May	7 May
Cultivar	Darko	Crimson Globe
1st fungicide application	8 May	8 May
2nd fungicide application	4 June	4 June
Plant vigour & disease assessment	23 June	-*
3rd fungicide application	7 July	7 July
Plant vigour & disease assessment	23 July	23 July
4th fungicide application	5 August	5 August
5th fungicide application	4 September	4 September
Plant vigour & disease assessment	4 September	4 September
Plant vigour & disease assessment	7 October	-
Harvest & final assessments	3 December	21 November

** crop not emerged sufficiently for assessments to be conducted*

Trial Site 1 (Westwoodside)

At this site establishment was relatively poor, especially in some low lying areas of the field. At the cotyledon stage leaf discoloration (reddening/purpling) was observed across the trial area and close inspection showed evidence of hypocotyl discoloration (blackening) and seedling collapse. Samples of affected seedlings were returned to the laboratory for detailed examination. Black-leg caused by the soil-borne fungus *Aphanomyces cochlioides* was confirmed on all the affected seedlings and was considered to be the primary cause for the establishment problems at this site. Perhaps not surprisingly there was a significant difference in this regard between the sterilised and unsterilised plots (Figure 1). Unfortunately, none of the individual applied chemical treatments in the trial provided complete control of the disease though some may have given a slight reduction in disease severity.

Figure 1 : Severity of *Aphanomyces* infection at trial Site 1 (Westwoodside), its impact on plant vigour and efficacy of sterilisation, June 2003

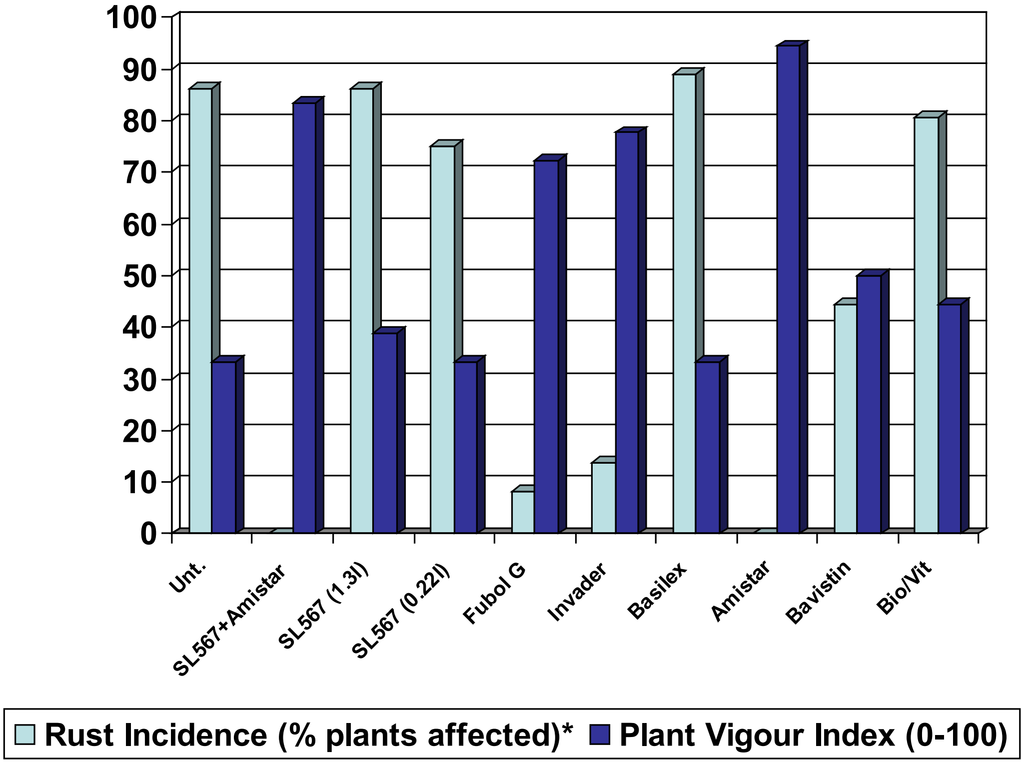


Because of the high drilling density at this site sufficient plants survived to justify taking the trial through to crop maturity. Whilst low levels of downy mildew developed on the foliage/crown tissues of occasional plants in the trial area by July few RMD symptoms could be found and where present the symptoms were very mild and this could have been caused by other factors. By crop maturity in October-November there was a negligible level of RMD in any of the trial plots. Apart from a general effect in overall plant vigour (due largely to the impact of the *Aphanomyces*) the only other visible effect in the crop during establishment was a marked reduction in weed growth in the sterilised area compared with the non-sterilised area. However, by late November some plots appeared to remain more vigorous with strong top growth compared to other less vigorous plots where the foliage had died back following early frosts (Plate 5).

Plate 5 : Prolonged greening and improved plot vigour in treated plots, November 2003

Interestingly, an assessment of plot vigour made on 3 December highlighted a strong correlation between the applied treatments with Amistar, Fubol Gold, Invader and, to a lesser extent, Bavistin providing significantly improved crop vigour. Close inspection of the disease assessment data also shows a strong correlation with rust (*Uromyces betae*) in the trial crop (Figure 2) and this almost certainly accounts for the improved foliage vigour late in the crop. In the case of Fubol Gold and Invader it is considered that the dithiocarbamate component of the fungicide mixture is likely to have provided considerable protectant activity against this disease.

Figure 2 : Relationship between the incidence of the leaf disease rust (*Uromyces betae*) and overall plant vigour at Site 1 (Westwoodside), November 2003



** sterilised plots only included in this assessment*

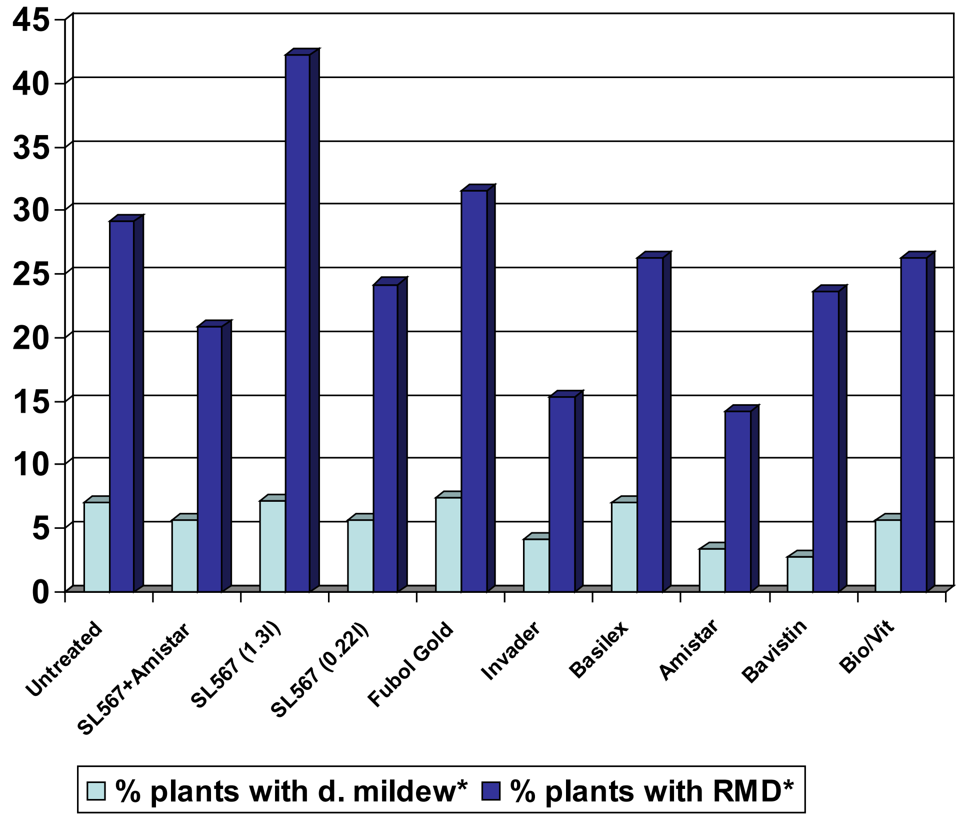
Due to the lack of a significant development of RMD in this trial site and the absence of downy mildew or any other potential cause for root malformation no further assessments were conducted though the site will be retained *in situ* over-winter.

Trial Site 2 (West Butterwick)

At this site seedling germination was slower than at Site 1 and this was due in part to the relatively wet heavy land used for the site and emergence occurred over a longer time period. Ultimately, plant density at this site was much lower though it did not suffer any apparent problems with *Aphanomyces cochlioides*. Downy mildew was found on occasional plants in the trial site on 23 July and continued at low-moderate levels as the season progressed. Surprisingly, this infection appeared, during routine visual inspection, to be irrespective of any of the applied fungicides. Plants with RMD symptoms were also observed on 23 July and a detailed assessment *in situ* at this early stage in the trial hinted at a possible correlation between the presence of this obligate pathogen and the occurrence of RMD on the same 'infected' plants.

However, as none of the applied fungicides eliminated downy mildew from the trial plots during the season, even after 4-5 fungicide applications (Figure 3), it was difficult to determine whether earlier observations suggesting a possible link between the two symptoms was valid. Whether the continued incidence of d. mildew in the trial plots is connected to the occurrence of RMD remains uncertain and continues to be open to speculation. Statistical analysis of the data may reveal some correlations at this site, once conducted.

Figure 3 : Incidence of downy mildew and RMD in trial site 2 (West Butterwick) September 2003



** Mean of unsterilised and sterilised plots*

In final assessments in November (Figures 4 & 5) downy mildew could still be found at relatively low levels in most plots. In the unsterilised area Invader appeared very effective against both d. mildew & RMD (Figure 4). However, a similar result was not achieved in the sterilised trial area (Figure 5) and this variability makes interpretation of the trial data very difficult. Generally, the incidence of d. mildew and RMD was reduced in the sterilised area, as compared to the equivalent unsterilised plots, though was not eliminated completely (Figure 6). This suggests that there may be a soil-borne phase to the disorder though, at the same time, also indicates that there may be other inoculum sources which has allowed the problem to occur even in sterilised plots.

Figure 4 : Incidence of downy mildew and RMD – mean of <u>unsterilised</u> plots at Site 2 (West Butterwick) November 2003

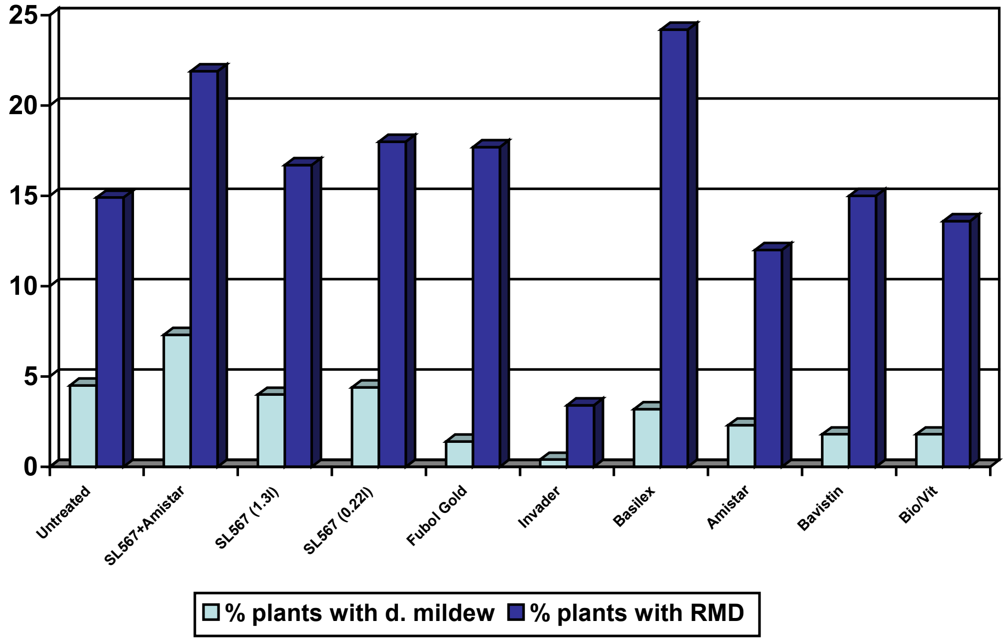


Figure 5 : Incidence of downy mildew and RMD – mean of <u>sterilised</u> plots at Site 2 (West Butterwick) November 2003

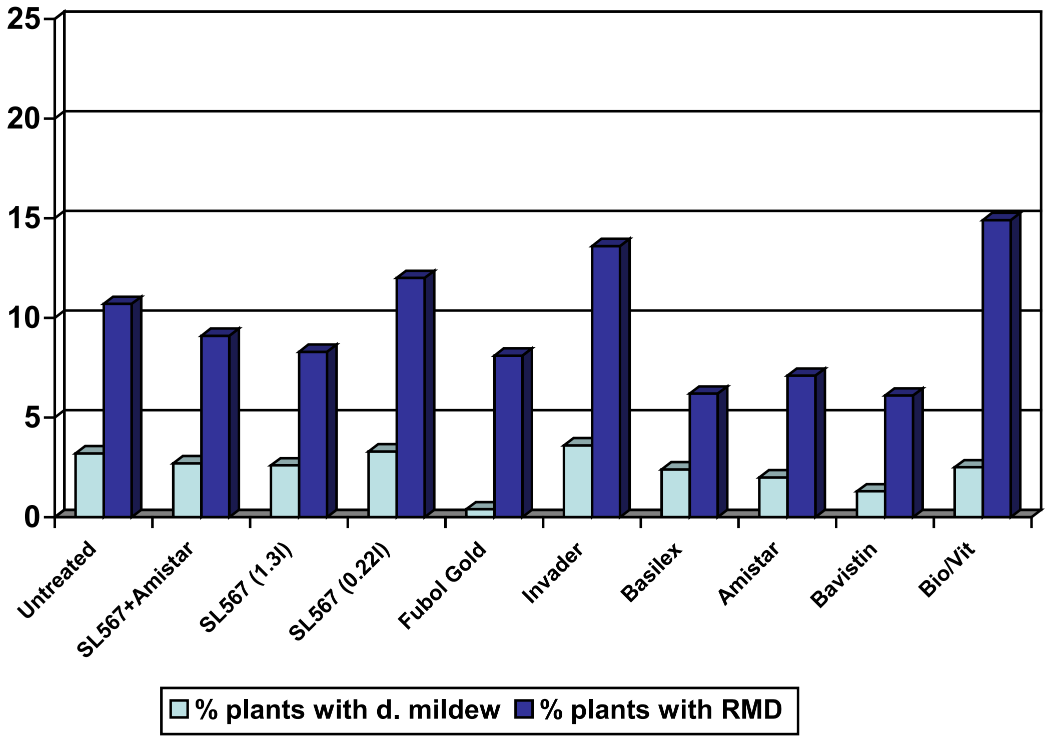
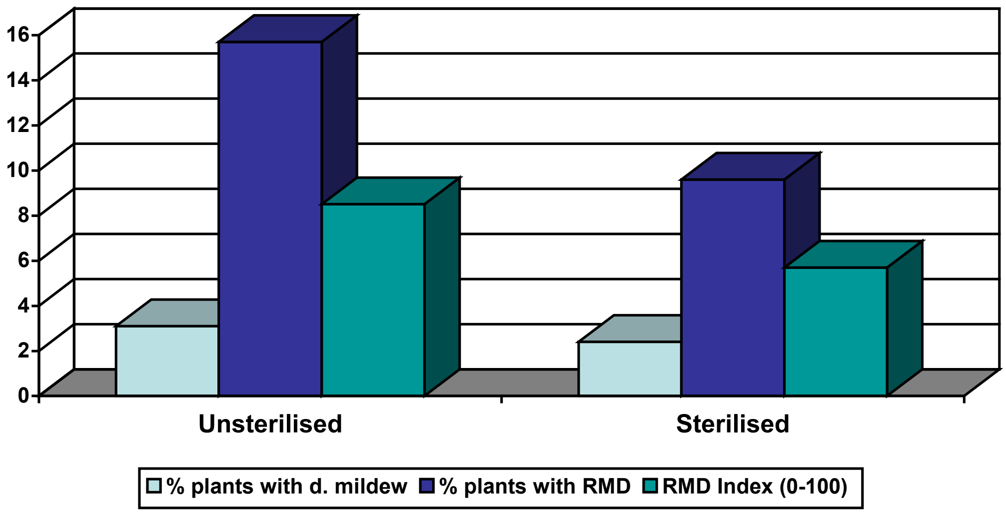
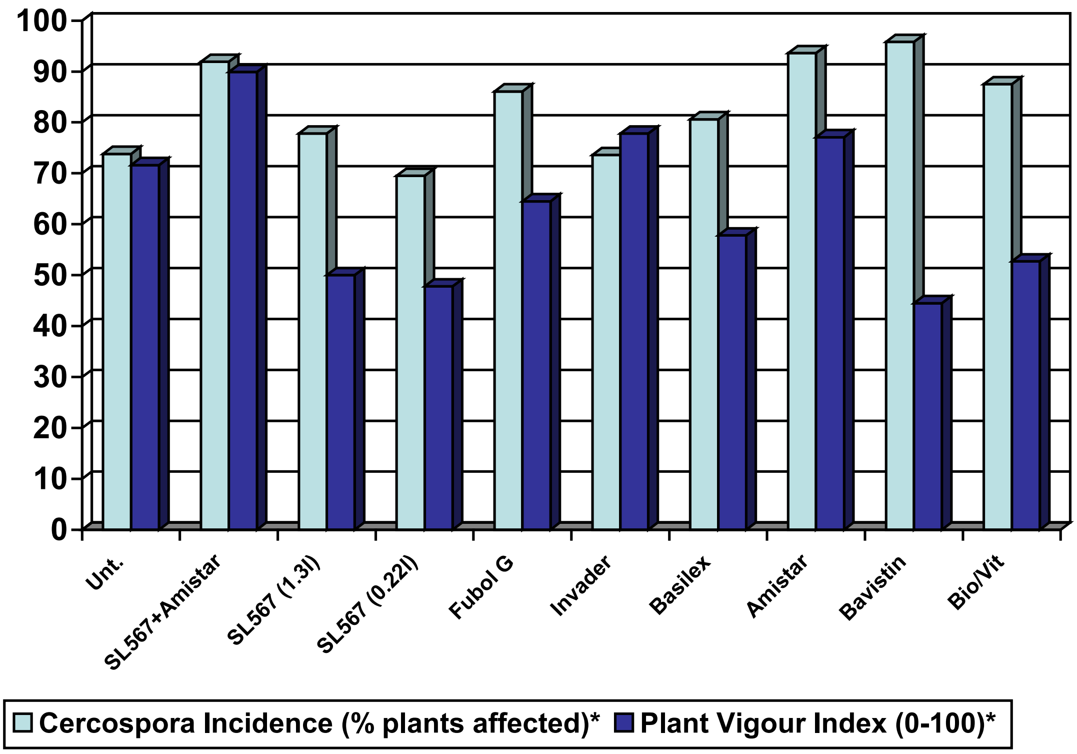


Figure 6 : Incidence of downy mildew and RMD – Mean of unsterilised and sterilised treatments at Site 2 (West Butterwick), November 2003



An improved plant vigour was also noted at this site in late Autumn though this appeared to be unrelated to the presence of leaf disease in the crop. Unlike at Site 1, there was little rust at this site and instead *Cercospora* leaf-spot predominated. This appeared not to be well controlled with any of the applied fungicides (Figure 7) and there appeared to be little or no correlation between this disease and plant vigour in late November 2003. The improved plant vigour observed in certain plots at site 2 cannot therefore be accounted for at this stage.

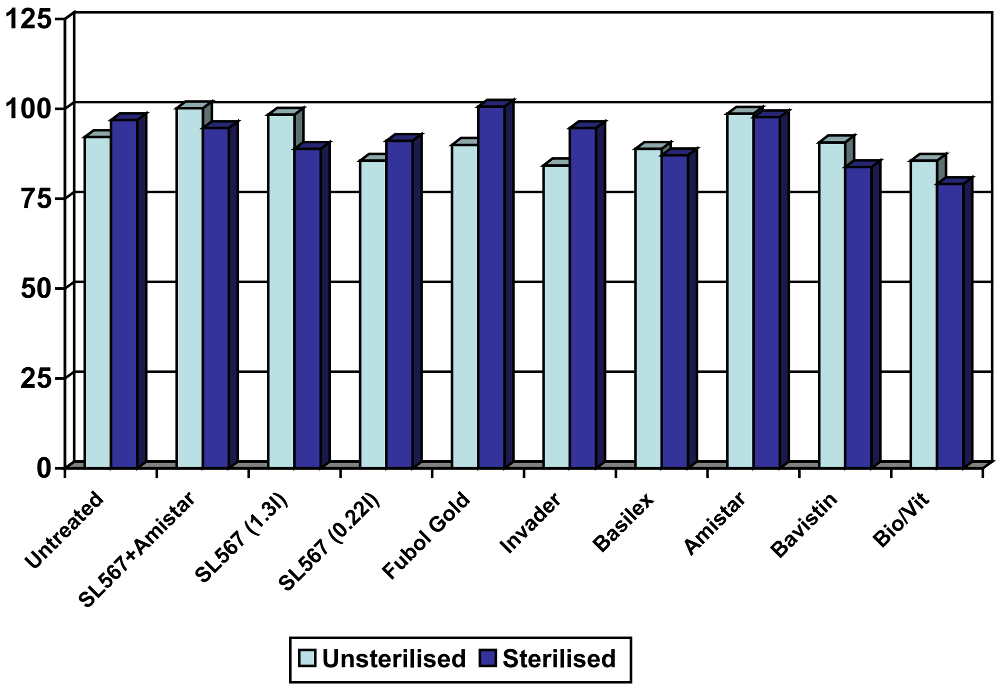
Figure 7 : Incidence of *Cercospora* leaf-spot and plant vigour at trial site 2 (West Butterwick), Autumn 2003



** Mean of unsterilised and sterilised plots*

Finally, yield data collected at this site indicated that there had been little impact of the various fungicide treatments on the total bulk weight of the crop (Figure 8). Even the soil sterilisation treatment appeared to have little effect in this regard.

Figure 8 : Total yield (tonnes/ha) for unsterilised and sterilised plots at Site 2 (West Butterwick) November 2003



In summary, it would appear from this trial that downy mildew was the only known disease to occur at appreciable levels in the site, though this was not particularly well controlled by the various applied fungicides, and this is particularly surprising. It may be that the 4 week interval between applications was insufficient and a shorter time between sprays may be required in future.

RMD did occur in this trial crop though was somewhat sporadic and variable in its occurrence; whilst there initially appeared to be a correlation between d. mildew infected plants and the development of RMD this effect appeared to become less clear as the season progressed. By the end of the trial it was evident that there had been some suppression of RMD following soil sterilisation, suggesting a possible soil-borne phase to the problem. Application of the various fungicides gave mixed results which cannot be readily explained, though this may relate to the relatively poor control of d. mildew.

(ii) The role of weed hosts for downy mildew development

Downy mildew has also been observed at high levels in recent years on *Chenopodium album* or 'fat-hen' a common weed in UK agriculture, including in red beet crops (Plate 6a & 6b). Whether this strain was the same as that infecting red beet remained uncertain at commencement of the work programme though it was considered that the increased acreage of 'set-aside' in the last 5 years could potentially have accounted for an upsurge in both the weed host and inoculum of this air-borne pathogen.

Plate 6 : Occurrence of downy mildew in the common weed 'fat-hen' (*Chenopodium album*) adjacent to a field of red beet in the Isle of Axholme, 2003.

A detailed search of the scientific literature using an extensive series of key-words (downy mildew, *Peronospora farinosa*, *Peronospora schactii*, *Chenopodiaceae*, *Chenopodium album*, beet, beetroot, red beet, *Beta vulgaris*, sugar beet, goosefoot, fat-hen, cross-inoculation, spinach, *Spinacia oleracea*, chard, weeds, strain variation) has now demonstrated that they are in fact different strains of *P. farinosa* as follows:-

- *Peronospora farinosa* f. sp. *betae* on Red Beet & Sugar Beet
- *Peronospora farinosa* f. sp. *chenopodii* on Quinoa and other *Chenopodium* species, including *C. album* or 'fat-hen'
- *Peronospora farinosa* f. sp. *spinaciae* on Spinach (*Spinacia oleracea*)

The inference from this historic cross-inoculation work (references provided) is that the downy mildew (*P. farinosa* f.sp. *chenopodii*) observed on 'fat-hen' or goosefoot (*Chenopodium album*) in beet crops presents no risk to red beet or sugar beet crops in the vicinity as these are only susceptible to the host specialised form of the pathogen (*P. farinosa* f.sp. *betae*).

(iii) Other observations in Red Beet crops during 2003

During Autumn 2002 and during the 2003 cropping season it became evident during close examination of affected crops and in talking with industry representatives that other symptoms were, on occasions, associated with RMD. RMD affected plants frequently, though not exclusively, developed an orange-brown discoloration of the petioles (Plate 7). The symptom was considered very similar to the colour generated on beet leaves known to be systemically infected in the crown. It should be noted however that, in some cases, this brown petiole symptom may also be a varietal characteristic and therefore cannot be used alone to distinguish RMD affected plants in a crop.

Plate 7: Orange-brown discoloration of petioles in RMD affected & downy mildew infected red beet. The brown petiole symptom is often observed alone in plants with no visible mildew symptoms.

In some crops, particularly during the dry summer conditions of 2003, it was possible to identify RMD affected roots by the erect nature of the central crown leaves. Whereas healthy plants were wilting due to a significant soil moisture deficit the central leaves of RMD affected plants remained erect. This may be due to the reduced sugar content of the leaves or possibly a response from the thicker tap root present on many of the RMD affected plants.

(i) Tagging plants

In one commercial crop inspected during late August 2003 the incidence of downy mildew was found to be relatively high. It was decided to 'tag' plants which showed 3 distinct symptoms:-

1. Healthy plants, no downy mildew or other symptoms visible
2. Crown infection with downy mildew, sporulation clearly evident
3. Brown petiole symptom, no sporulation of downy mildew

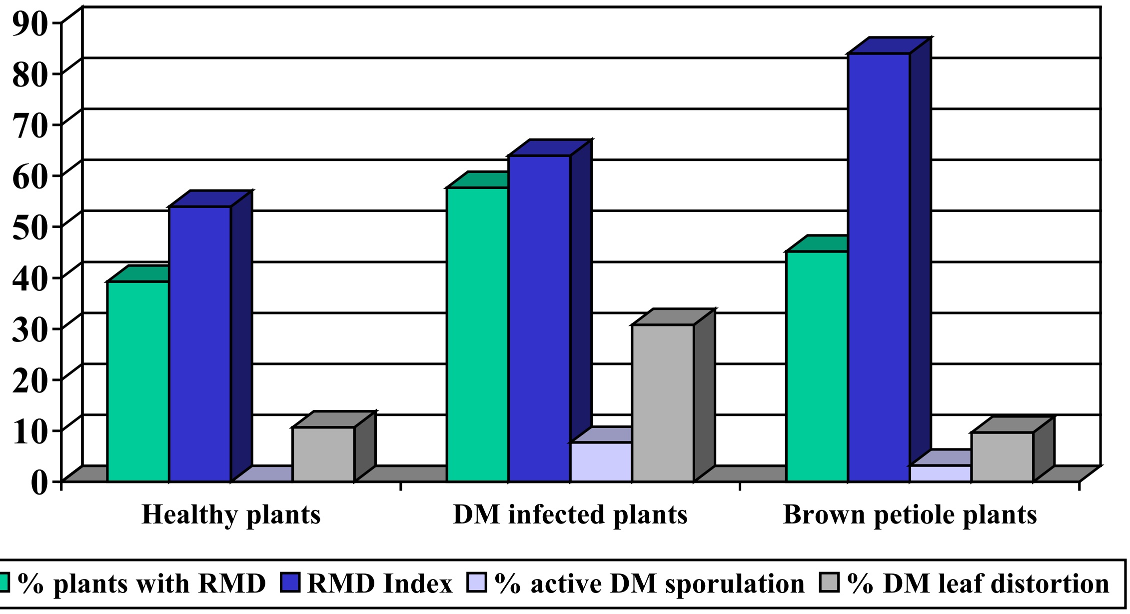
The plants in the 3 categories above were identified and tagged on 4 September and then the crop was left undisturbed until near harvest at which time the plants in the three categories were lifted and returned to the laboratory for detailed assessment. At the time the plants were lifted on 7 October there was a relatively high incidence of RMD. Many of the plants were wilting due to a high soil moisture deficit yet RMD affected plants were more prominent because they stood more erect in the crop.

Results of the assessments are presented in Table 3 and charted in Figure 9 below.

Table 3 : Harvest assessments from tagged plants in a commercial crop exhibiting a range of different symptoms possibly associated with RMD

Harvest Assessments	**Healthy**	**Downy mildew infected**	**Brown petiole affected**
% of tagged plants which developed RMD	39.3	57.7	45.2
RMD Index (distortion severity) on tagged plants	2.7	3.3	4.2
% tagged plants with active sporulation of d. mildew	0.0	7.7	3.2
% tagged plants with leaf distortion due to d. mildew	10.7	30.8	9.7
% of tagged plants with d. mildew sporulation & RMD	0.0	7.7	3.2
% of tagged plants with d. mildew leaf distortion and RMD	7.1	30.8	9.7

Figure 9: Representation of observational studies in a commercial red beet crop during 2003



Interestingly, on the plants which were visibly free of d. mildew infection at the time of tagging 39% developed RMD symptoms (Table 3 & Figure 9). This could either be due to latent infection not visible at the time of tagging or that they became infected later after the tagging had been completed. There was a much higher incidence of RMD in plants which were visibly infected with d. mildew at the time of tagging and this is highly significant. Also, those plants with a brown petiole symptom also had a higher incidence of RMD, though interestingly in this study, the severity of RMD was greatly increased.

It may be appropriate to undertake more of this type of 'tagged' monitoring in subsequent crops to further investigate a possible link between the various symptoms.

(ii) Monitoring the 'brown petiole' symptom

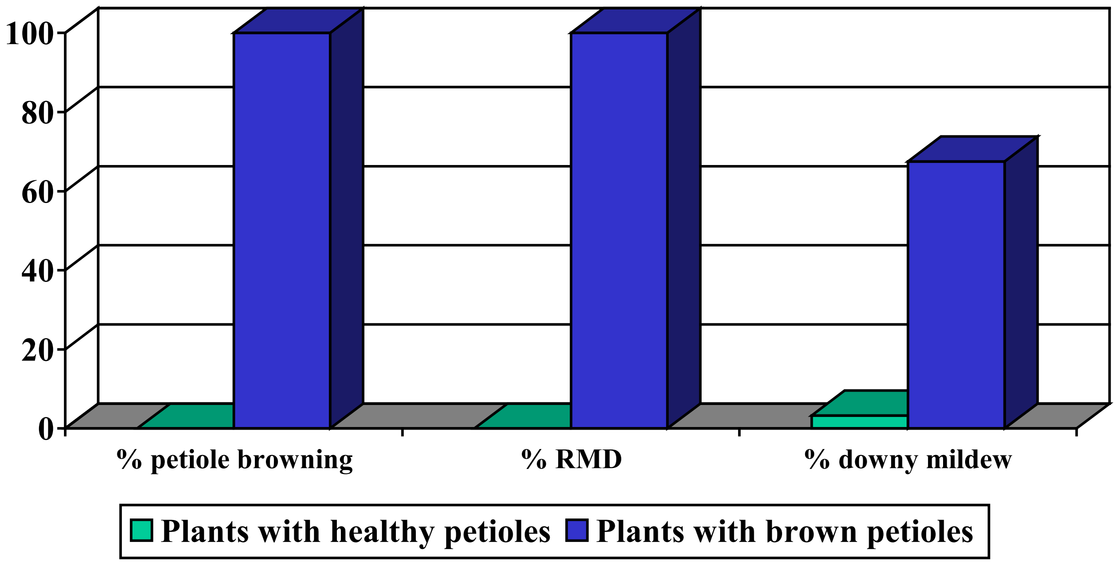
In a separate observational study in a red beet crop which exhibited brown petiole symptoms in November 2003 we collected 10-15 healthy and 10-15 'brown petiole' plants from 2 random areas of the crop. We returned these to the laboratory for assessment of RMD and associated symptoms., the results for which are presented in Table 4 & Figure 10.

What is particularly interesting is that there again appeared to be a strong correlation between the incidence of the 'brown petiole' symptom and RMD. Where healthy plants were randomly selected from this crop ie no 'brown petiole' evident, the incidence of RMD was zero. However, in contrast, in all cases where plants were selected which exhibited a 'brown petiole' symptom RMD was present on the root. Of even more significance was that we found a very low incidence (3.3%) of downy mildew on the plants with healthy petioles whereas on the plants with 'brown petiole' symptoms 68% of the plants exhibited d. mildew in the crown tissues.

Table 4 : Assessment of plants with or without brown petiole symptoms selected from a commercial field crop.

Sample No.	% petiole browning	% RMD	% downy mildew
Healthy petiole 1	0.0	0.0	0.0
Healthy petiole 2	0.0	0.0	6.7
MEAN	**0.0**	**0.0**	**3.3**
Petiole browning 1	100.0	100.0	63.6
Petiole browning 2	100.0	100.0	71.4
MEAN	**100.0**	**100.0**	**67.5**

Figure 10 : Observations of a possible relationship between the brown petiole symptom and RMD in a commercial crop in the Isle of Axholme in 2003.



Preliminary results for the various trials and observations during 2003 are mixed though it is evident that the hypothesis of a possible link between systemic infection with d. mildew and RMD has not been proven, though equally it has not been disproven either. It has been particularly unfortunate (from an experimental basis) that 2003 proved climatically to be unusual and not conducive to the development of wet weather diseases such as d. mildew as this marred our chances of finally elucidating the cause of RMD in red beet.

There is no doubt that the potential association between d. mildew and RMD needs resolving with the utmost of urgency so that other in-depth investigations can be undertaken to find effective control measures for RMD if indeed it turns out to be caused by some other as yet unidentified factor. Until then it is critical that every effort is made to determine whether RMD affected roots are systemically infected with *Peronospora farinosa* f. sp. *betae.* It is recommended that, in addition to further fungicide trials to evaluate potential control measures, a novel approach using either serology (antiserum) or DNA based technology ie PCR (Polymerase Chain Reaction) is used to confirm or refute the current hypothesis during 2004.

Financial Benefits

It is too early judge the financial benefits from this work though there continues to be a strong economic justification for the work assuming we can elucidate the cause of RMD and provide the industry with robust control measures. In the absence of this assurance some growers are already reducing acreage of red beet in high risk areas. If the problem were to reappear at high levels in subsequent seasons without adequate safeguards RMD would undoubtedly be of considerable economic concern to many red beet growers.

Action Points for Growers

- Be aware of the risk from RMD in red beet and thre potential economic significance should it occur.
- Monitor crops closely in 2004 for the early signs of downy mildew, root malformation or other possible symptoms that may be associated with the problem.
- Look at the economics of soil sterilisation on the farm and consider this for high risk situations ie land which has grown beet intensively in the last few years.
- Only use beet seed from a reputable source and consider the potential risk of seed-borne disease.
- Use seed treatment containing metalaxyl-M, where possible, to minimise the risk from downy mildew and other potential pathogens from infecting the beet at emergence.
- Apply approved fungicides for downy mildew as a preventative measure until such time that a link between the disease and RMD can either be established or dis-proven.
- Liaise closely with the Red Beet Technology Group and the HDC Technical Manager to ensure you have the latest information relating to this important problem in the crop.
- Where possible, provide support to ongoing research and development into the problem of RMD aimed at elucidating the primary cause and identifying effective control measures.