Contract report for the
Horticultural Development Council

Celery: evaluation of alternative seed treatments for the control of *Septoria apiicola* (celery leaf spot)

FV 237a

Final Report

September 2007

Project title:	Celery: evaluation of alternative seed treatments for the control of *Septoria apiicola* (celery leaf spot)
Project number:	FV 237a (extension)
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The results and conclusions in this report are based on a series of experiments 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

I 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.

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1 GROWER SUMMARY

1.1 Headline

Pre-soaking celery seed for 1-6 hours prior to hot water treatment (48°C, 30 minutes) did not reduce percentage seed germination compared with either the untreated control or the hot water treatment only. For one of two seed batches, a pre-soak of 24 hours reduced percentage germination compared to the hot water treatment only.

1.2 Background and expected deliverables

The aim of project FV 237a was to determine the efficacy of a range of seed treatments for celery Septoria that could provide alternatives to thiram for both conventional and organic celery production.

Conclusions from that project (also see FV 237a Final Report) were as follows:

- Hot water treatment (48°C, 30 minutes) without a pre-soak is the best option available for treatment of organic celery seed to control *Septoria apiicola* (celery leaf spot) at 0present.
- Under specific conditions, celery seed treatments with hot water, Jet 5 (peroxyacetic acid) and Wakil XL (cymoxanil + metalaxyl-M + fludioxonil) gave significant reductions in the levels of *Septoria apiicola* in celery seed, without affecting seed vigour. However, the industry standard treatment (warm water thiram soak) was the only treatment tested that eliminated *S. apiicola*.

Without the option for use of thiram-treated seed or a prophylactic spray regime in organic celery production, it is anticipated that substantially higher levels of loss due to celery leaf spot, could occur in future. Use of hot water treatment is now being considered for use on organic celery seed on a commercial scale. At a meeting to review project FV 237a, industry representatives proposed that further work to optimise hot water treatment of celery seed (increasing pathogen kill without deleterious effects on seed germination) would be highly relevant.

From the findings of project FV 237a, the disinfectant peroxyacetic acid was highlighted as a possible alternative seed treatment for control of *S. apiicola* in conventional celery production. In particular, it was considered that a soak treatment could be incorporated as part of the priming process. Again, industry representatives proposed that further studies to

optimise application rates and treatment durations for the control of *S. apiicola* on celery seed were warranted.

For these reasons, project FV 237a was extended, to focus on optimising hot water and disinfectant treatments for the elimination of *S. apiicola* from celery seed.

Overall project aim:
To determine the efficacy of selected hot water treatments and disinfectants in controlling *Septoria apiicola* on celery seed.

Specific objectives:

- Conduct a preliminary study to confirm the mean percentage of seeds with viable Septoria infection in the seed batch to be used.
- Determine the effect of pre-soak duration (e.g. 1, 2, 4, 8 and 24 hours) on the efficacy of hot water treatment (48^{o}C, 30 minutes).
- Determine the effect of peroxyacetic acid concentration and soak duration on seed treatment efficacy (six treatments and an untreated control).

1.3 Summary of the project and main conclusions

Testing celery seed for viable Septoria infection

Thirteen seed batches naturally infected with *S. apiicola* (including organic and conventional seed) were sourced over a 2-year period from a commercial seed company and tested for viability of *S. apiicola*, in order to identify a batch for use in subsequent seed treatment efficacy tests. Despite the presence of fruiting bodies typical of *S. apiicola* on the seed, and release of spores from the fruiting bodies, none of the spores were viable. Reasons for this were not fully clear, although storage duration can affect the viability of *S. apiicola* on celery seed. It was concluded that none of the seed batches sources was suitable for testing the effects of seed treatment on pathogen viability. However, it was considered that testing for effects of treatments on seed germination could proceed. Infected seed batches were used for seed germination tests in this work, since hot water treatment on a commercial scale is most likely to be used for infected seed, which can be more prone to deleterious effects from physical treatments than healthy seed.

Hot water treatment

Anecdotal evidence and previous results from FV 237a (using a 16 hour pre-soak) suggest that seed soaking in water can increase the efficacy of subsequent hot water treatment, by 'activating' the pathogen. In this project extension, the effect of pre-soaking on levels of *S. apiicola* could not be determined due to lack of a suitable seed batch for testing.

The effects of different pre-soak treatments (0, 1, 2, 4, 6 and 24 hours) prior to hot water treatment (48°C, 30 minutes) on celery seed germination was tested using two seed batches. Pre-soak durations of 1-6 hours prior to hot water treatments did not reduce percentage seed germination compared with the untreated control or the hot water treatment only. This type of pre-soak could be used commercially if it was found subsequently to also improve the level of pathogen kill by hot water treatment. For one seed batch, a long pre-soak (24 hours) had a deleterious effect on seed germination in comparison with the hot water treatment only, in agreement with previous results from FV 237a, where a pre-soak of 16 h was also found to reduce seed germination.

In agreement with previous research on other vegetable crops, it was found that the two celery seed batches tested varied in their sensitivity to hot water treatment, due probably to factors such as seed age or levels of infection. Protocols developed for hot water treatment on a commercial scale should take account of this variability.

Disinfectant treatment

The effects of Jet 5 (peroxyacetic acid) at different rates, soak durations, and with or without a pre-soak on celery seed germination was tested using one seed batch. Treatment with Jet 5 (peroxyacetic acid) under a range of conditions increased percentage seed germination, with best results achieved when a 16 hour pre-soak in water was followed by a 1 hour soak in 2% Jet 5.

It should be noted that Jet 5 cannot be developed as a commercial seed treatment, since under current legislation peroxyacetic acid (Jet 5) is approved in the UK only for use on: flower bulbs, potato tubers, disinfection of glasshouses, warehouses and agricultural tools and equipment.

1.4 Financial benefits

Outbreaks of leaf spot caused by *Septoria apiicola* are observed annually on celery crops grown to organic standards, with seed known to be the main source of inoculum for the disease. Use of clean seed is key to disease management and hot water treatment is currently the main option for control of *S. apiicola* on organic celery seed. Methods shown to reduce the deleterious effects of hot water treatment on seed vigour while increasing pathogen kill will have benefits for the seed industry, propagators and growers.

1.5 Action points for the industry

- Where possible, monitor seed crops to ensure that they are free from symptoms of celery leaf sport caused by *Septoria apiicola.*
- Celery seed should be tested for *S. apiicola* using methods that quantify viable infection.
- For organic celery production, hot water treatment is the best available option at present for reducing infection due to *S. apiicola*, using the following conditions:
  - Pre-soaking may be used to increase the efficacy of hot water treatment. It should be noted that the effects of pre-soak durations will vary with seed batch according to seed age and infection levels.
  - Treat the seed for 30 minutes at 48^{o}C.
- Having ensured that disease-free seed is being used, propagators and growers should follow guidelines for minimising the risk of celery leaf spot development during field production, using cultural and chemical controls outlined in HDC Factsheet 09/04.

2 SCIENCE SECTION

2.1 Introduction

The aim of project FV 237a was to determine the efficacy of a range of seed treatments for celery Septoria that could provide alternatives to thiram for both conventional and organic celery production.

Conclusions from that project (also see FV 237a Final Report) were as follows:

- Hot water treatment (48^{o}C, 30 minutes) without a pre-soak, is the best option available for treatment of organic celery seed to control *Septoria apiicola* (celery leaf spot) at present.
- Under specific conditions, celery seed treatments with hot water, Jet 5 (peroxyacetic acid) and Wakil XL (cymoxanil + metalaxyl-M + fludioxonil) gave significant reductions in the levels of *Septoria apiicola* in celery seed, without affecting seed vigour. However, the industry standard treatment (warm water thiram soak) was the only treatment tested that eliminated *S. apiicola*.

Without the option for use of thiram-treated seed or a prophylactic spray regime in organic celery production, it is anticipated that substantially higher levels of loss due to celery leaf spot, could occur in future. Use of hot water treatment is now being considered on a commercial scale for use on organic celery seed. At a meeting to review project FV 237a, industry representatives proposed that further work to optimise hot water treatment of celery seed (increasing pathogen kill without deleterious effects on seed germination) would be highly relevant.

From the findings of project FV 237a, the disinfectant peroxyacetic acid was highlighted as a possible alternative seed treatment for control of *S. apiicola* in conventional celery production. In particular, it was considered that a soak treatment could be incorporated as part of the priming process. Again, industry representatives proposed that further studies to optimise application rates and treatment durations for the control of *S. apiicola* on celery seed were warranted.

For these reasons, project FV 237a was extended, to focus on optimising hot water and disinfectant treatments for the elimination of *S. apiicola* from celery seed. The specific objectives were to:

- Conduct a preliminary study to confirm the mean percentage of seeds with viable Septoria infection in the seed batch to be used.

- Determine the effect of pre-soak duration (e.g. 1, 2, 4, 8 and 24 h) on the efficacy of hot water treatment (48^{o}C, 30 min).
- Determine the effect of peroxyacetic acid concentration and soak duration on seed treatment efficacy (six treatments and an untreated control).

2.2 Testing celery seed for viable Septoria infection

2.2.1 Introduction

Seed testing was done in order to identify a batch of celery seed naturally infected with viable *Septoria apiicola* for use in experiments on seed treatment efficacy.

2.2.2 Methods

Thirteen seed batches naturally infected with *Septoria apiicola* (including organic and conventional seed) were sourced throughout the project extension from a commercial seed company (Table 1). The seed batches (including the batch used previously from FV 237a) were tested for viability of *S. apiicola*, in order to identify a batch that would be suitable for use in subsequent seed treatment efficacy tests. All of the batches were tested in 2004, except for batch 6057, which was tested in 2006.

Celery seed infected with *Septoria apiicola* usually bear pycnidia of the fungus, which exude spores when wetted. The simplest methods of quantifying seed infection involve recording the percentage of seed with visible pycnidia or determining the percentage of seeds that exude *S. apiicola* spores when placed in individual water droplets. The limitation of these methods is that they do not provide information on spore viability (ability to germinate and infect the host). The following techniques (based on methods developed and used successfully in FV 237a) were used:

Presence of pycnidia of *S. apiicola*

Celery seed batches received for testing were examined under a low-power microscope for the presence of pycnidia on seed, as a preliminary indication of infection by *S. apiicola*.

Spore release and percentage germination

For each seed batch, three random samples of 100 seeds were taken. The seeds were plated (five per plate) on to potato dextrose agar amended with streptomycin (PDA+S). A droplet of sterile distilled water (SDW) was pipetted on to each seed. The plates were incubated for 24 hours at 20°C. The seeds were examined using an inverted high power microscope, to determine the percentage of seeds for which spores of *S. apiicola* had been released, and for which spore germination had occurred.

To check the possibility that inhibition of germination of *S. apiicola* spores was occurring on PDA+S due to a component of the agar medium, seeds with visible pycnidia from batch 6057 were plated in droplets of SDW on V8 agar (five seeds on each of four plates). The

plates were incubated at 20ºC, and then checked for spore release after 24 hours.

2.2.3 Results and discussions

Despite testing a range of celery seed batches visibly infected with *S. apiicola*, it was not possible to source a seed batch on which the pathogen was viable. The results in Table 1 show that pycnidia of *S. apiicola* were visible on all of the 13 seed batches tested. Nine batches that had in excess of 4% seeds with pycnidia were tested further for spore release and viability. For six out of nine batches, release of spores of *S. apiicola* was observed microscopically. However, the percentage of seeds that showed spore release and spore germination (indicating viability) was zero for all but one batch which had less than 1% seeds with spore germination. The results confirm previous commentary (Maude, 1996) that presence of pycnidia on celery seed, while providing an indication of infection by *S. apiicola*, does not give an accurate measurement of pathogen viability.

Batches 37/1169 and 37/580 were sourced prior to this project extension, with 37/1169 being used extensively for earlier experiments in FV 237a. Similar tests in 2002, showed that the percentage of seeds in batch 37/1169 with viable Septoria infection was 10%, based on observation of release and germination of spores from seeds plated on agar plates in individual water droplets (see FV 237a Annual Report, December 2002). The low incidence of seeds with spore germination from 37/1169 and 37/580 (both harvested in 2002 or earlier), suggests that a decline in spore viability had occurred during seed storage, in agreement with results from Krout (1921). However, prolonged storage duration was a less likely cause of reduced pathogen viability for the other seed batches, which were harvested post-2002 and tested in 2004, except for batch 6057 that was harvested in 2005 and tested in 2006.

Seed batch 6057, in particular, had a relatively high incidence of seed with pycnidia (>10%), and seeds from which spores of *S. apiicola* were released (21%). As this seemed a promising batch to use in subsequent experiments, plating tests were repeated but results confirmed nil spore germination. It is possible that spore germination could be inhibited by a component of the agar used for seed plating; however, this seemed unlikely since the method worked consistently well when used previously in project FV 237a, and has subsequently worked in studies for FV 318 when used for germination of spores of parsley Septoria (*S. petroselini*). In addition, nil spore germination occurred when celery seeds with pycnidia from batch 6057 were plated onto V8 agar, which is routinely used for culturing of *Septoria* species.

Reasons for non-viability of *S. apiicola* on the seed batches could not be fully ascertained. It

was concluded that none of the seed batches sourced was suitable for rigorous testing for the effects of seed treatment on pathogen viability. However, testing for effects of treatments on seed germination of infected seed could proceed. For this purpose, batches 2004/8 and 6057 were used. Use of infected rather than healthy seed batches for seed germination tests contrasted with methods used for experiments in FV 237. This was appropriate as hot water treatment on a commercial scale is most likely to be used for infected seed batches, and results from other crops have indicated that both infected and older seed batches may be more prone to deleterious effects from physical seed treatments.

Table 1. Characteristics of celery seed batches tested for the presence of *Septoria apiicola*

Seed sample reference	**% seeds with pycnidia of *S. apiicola****	**% seeds with spore release after 24 h***	**% seeds with spore germination after 24 h***
37/1169	Present but not quantified	14	0.3
2004/1	2.3	Nt	Nt
2004/2	5.3	0	0
2004/3	0.3	Nt	Nt
2004/4	8.0	0	0
2004/5	0.3	Nt	Nt
2004/6	4.3	0	0
2004/7	0.7	Nt	Nt
37/580	Present but not quantified	3.3	0
2004/8	Present but not quantified	15.6	0
2004/9	Present but not quantified	7.8	0
2004/10	Present but not quantified	1.3	0
6057	>10	20.7	0

* 3 reps of 100 seed (except for 2004/8, 9 and 10; 77 seeds per batch)
Nt Not tested

2.3 Hot water treatment

2.3.1 Introduction

The objective was to test the effect of pre-soak duration on the efficacy of hot water treatment for control of *Septoria apiicola* in celery seed

2.3.2 Methods

Treatments listed in Table 2 were each applied to a 3 g seed sample (batch 2004/8) and replicated four times.

Table 2. Pre-soak and hot water seed treatments tested

Treatment No.	Pre-soak duration (h)	Hot water treatment (48°C, 30 min)
1	0	No
2	0	Yes
3	1	Yes
4	2	Yes
5	4	Yes
6	6	Yes
7	24	Yes

For treatments 3-7, seed samples were pre-soaked in distilled water at ambient laboratory temperature (approximately 20°C) for the appropriate duration prior to hot water treatment.

Seed samples were tied loosely in muslin, ensuring that there was sufficient room for seed swelling. The hot water bath was allowed to reach the correct temperature before immersing seed samples. The seed samples were gently agitated while they were being treated, to ensure that hot water was reaching all seeds. Once the hot water treatment was complete, seed samples were immersed in cold distilled water, to stop the heating process.

After pre-soaking and hot water treatments, seed samples were thoroughly air-dried in a laminar flow cabinet at ambient temperature (around 20°C) before continuing.

Seed germination tests were set up with four replicate samples of 50 seeds for each treatment. Seeds were placed in plastic boxes containing a 17.5 x 11.5 x 2 cm, pleated filter paper, moistened with SDW, with two lines of 50 seeds per box. The boxes were incubated at 20°C (8 h light/16 h dark) for up to 22 days. The boxes were checked approximately every 3 days to ensure the filter paper remained moist.

The seeds were assessed after 15 and 22 days and classified into the following categories:

- Normal: Cotyledons at least 50% present with no damage to terminal bud. Roots > 1cm.
- Weak: Roots 0.5 – 1 cm
- Abnormal: Roots <0.5 cm
- Fresh seed: Seeds which remain firm and apparently viable at the end of the test were classified as fresh ungerminated seed and reported separately from the percentage germination.
- Dead seed: Seeds which at the end of the test period were decayed, mouldy or soft, or had not produced any seedling or part of a seedling, were classified as dead seeds.

Despite low levels of pathogen viability on the seed lot, the following method was used to determine whether any treatment effect on pathogen survival could be ascertained. Seed from each treatment was placed in water in a conical flask. The flasks were placed on an orbital shaker for 2 hours. For each flask, 1 ml of liquid was pipetted into a universal tube and centrifuged at 2000 rpm for 10 minutes. The supernatant was discarded and the pellet resuspended in distilled water. For each treatment, the presence of *S. apiicola* spores was checked using a haemocytometer under a high-power microscope. For samples in which spores were observed, 100 ul spore suspension was spread onto each of 3 plates of PDA+S, incubated at 20^{o}C for 16-20 hours and percentage spore germination determined.

The experiment was repeated using seed batch 6057. Seed germination was assessed at 21 and 32 days after treatment.

2.3.3 Results and discussion

After treatments had been applied, percentage germination of *S. apiicola* spores was very low (<1%) or nil from seed batches 2004/8 and 6057 respectively (Table 3), in agreement with results from Section 2.3.3. Lack of viable pathogen in the untreated controls meant that pre-soak and hot water treatment effects on levels of *S. apiicola* could not be determined.

The percentage germination for untreated seed (treatment 1) from batches 2004/8 and 6057 (Table 4) was considerably lower than commercially acceptable seed germination standards (>90%). This was consistent with the presence of surface contaminants such as *Fusarium* and *Alternaria* species (observed during seed plating tests in Section 2.2) as well as infection due to *S. apiicola* (Table 4).

There was a significant effect of treatment on percentage seeds with normal germination from batch 6057 (Table 4). There was higher percentage germination for seeds from hot

water treatments with and without a pre-soak (0-6 h), compared with the untreated control. This increase is likely to have occurred due to a reduction in the level of seed-borne fungi and bacteria present on the seed at the time of germination. Pre-soaks of 1-6 hours did not significantly increase or reduce percentage germination compared to the hot water treatment without a pre-soak, but a pre-soak of 24 hours had a deleterious effect on seed germination.

For batch 2004/8, there was no significant effect of pre-soak or hot water treatment on seed germination. A variation in the response of different seed batches to hot water treatment has been reported previously. For example, results from an EU project on seed treatments for organic vegetable production demonstrated that seed batches of brassicas and carrot varied in sensitivity to physical treatment methods, depending on batch maturity (www.stove-project.net/Results.html). In addition results from HDC project FV 263 showed that onion seed batches containing moderate and high levels of *Botrytis allii* were more sensitive to hot water treatment than a botrytis-free seed batch.

In summary, anecdotal evidence and previous results from FV 237a (using a 16 hour pre-soak) suggest that seed-soaking in water can increase the efficacy of subsequent hot water treatment, by 'activating' the pathogen. In this experiment, the effect of pre-soaking on levels of *S. apiicola* could not be determined due to lack of a suitable seed batch for testing. Pre-soak durations of 1-6 hours prior to hot water treatments of 48°C for 30 minutes did not reduce percentage seed germination compared with the untreated control, or the hot water treatment only. This type of pre-soak could be used commercially if it was subsequently found to improve the level of pathogen kill by hot water treatment. A long pre-soak (24 hours) had a deleterious effect on seed germination in comparison with the hot water treatment only, in agreement with previous results from FV 237a, where a pre-soak of 16 h was also found to reduce seed germination.

Table 3. Effect of pre-soak and hot water treatments on germination of conidia of *Septoria apiicola* from celery seed

No.	Pre-soak duration (h)	Hot water treatment (48°C, 30 min)	% spore germination (Batch 2004/8)	% spore germination (Batch 6057)
1	0	No	0.7	0.0
2	0	Yes	0.5	0.0
3	1	Yes	0.9	0.0
4	2	Yes	0.3	0.0
5	4	Yes	0.2	0.0
6	6	Yes	0.6	0.0
7	24	Yes	0.2	0.0

Table 4. Effect of pre-soak and hot water treatments on percentage of celery seeds showing normal germination for two seed batches

No.	Pre-soak duration (h)	Hot water treatment (48°C, 30 min)	% seeds with normal germination (22 days) (Batch 2004/8)	% seeds with normal germination (32 days) (Batch 6057)
1	0	No	46.0	34.0
2	0	Yes	52.0	56.0
3	1	Yes	47.0	47.5
4	2	Yes	44.5	55.5
5	4	Yes	40.5	59.5
6	6	Yes	40.5	58.5
7	24	Yes	41.5	41.5
		D.f.	21	21
		S.e.d	5.2	6.9
		F. probability	0.307	0.008

2.4 Disinfectant treatment

2.4.1 Introduction

The objective was to test the efficacy of Jet 5 (peroxyacetic acid) for control of *Septoria apiicola* in celery seed.

2.4.2 Methods

Treatments listed in Table 5 were each applied to a 3 g seed sample (batch 6057) and replicated four times.

Table 2. Jet 5 seed treatments tested

No.	Pre-soak (16 h)	Jet 5 concentration	Jet 5 soak duration (hours)
1	No	Untreated control	0
2	Yes	2% (0.1% peroxyacetic acid)	1
3	Yes	5% (0.25% peroxyacetic acid)	1
4	No	2% (0.1% peroxyacetic acid)	1
5	No	5% (0.25% peroxyacetic acid)	1
6	No	2% (0.1% peroxyacetic acid)	6
7	No	5% (0.25% peroxyacetic acid)	6

For treatments 2 and 3, seed samples were pre-soaked in distilled water at ambient laboratory temperature overnight (20°C, 16 hours) prior to treatment with Jet 5.

The seed samples were tied loosely in muslin, ensuring that there was sufficient room for seed swelling. The samples were soaked in Jet 5 at the appropriate concentration for either 1 or 6 hours. The seeds were fully immersed and agitated periodically to ensure that all seeds were in contact with the disinfectant.

The seeds were thoroughly air-dried at ambient temperature (20°C) in a laminar flow cabinet. Seed germination tests were done as described in Section 2.3.3. Pathogen viability tests were not done, since results from previous experiments had demonstrated that *S. apiicola* was not viable on the seed batch used.

2.4.3 Results and discussion

Disinfectant treatment effects on levels of *S. apiicola* could not be determined due to lack of a suitable seed batch.

There was a significant effect of treatment on percentage normal seed germination (Table 6). One treatment (6 hour soak in 5% Jet 5) had a deleterious effect on seed germination compared to the untreated control. The remaining treatments improved seed germination compared to the untreated control, probably due to the elimination of contaminant micro-organisms. The most promising treatment was a 16-hour pre-soak in water followed by a 1 hour soak in 2% Jet 5, resulting in an increase from 48.5 to 82.5% normal seed germination.

Table 6. Effect of Jet 5 treatments on percentage of celery seeds showing normal germination for one seed batch (6057)

No.	Pre-soak (16 h)	Jet 5 concentration	Jet 5 soak duration (hours)	% normal seed germination (36 days)
1	No	Untreated control	0	48.5
2	Yes	2%	1	82.5
3	Yes	5%	1	67.5
4	No	2%	1	67.5
5	No	5%	1	74.5
6	No	2%	6	66.5
7	No	5%	6	27.5
			d.f.	21
			S.e.d.	7.8
			F. probability	<0.001

2.5 Conclusions

- Of 13 celery seed batches tested, all had visible pycnidia of *Septoria apiicola*, but none contained viable spores of the pathogen. Consequently, the effects of pre-soaks prior to hot water treatment, and disinfectants on the levels of *Septoria apiicola* on celery seed could not be determined.
- It was confirmed that the incidence of celery seeds with pycnidia of *S. apiicola* does not provide an accurate measurement of percentage seeds with viable infection.
- In two experiments, soak durations of 1-6 hours prior to hot water treatment (48°C, 30 minutes) did not reduce percentage seed germination compared with either the untreated control or the hot water treatment only. A pre-soak of 24 hours reduced percentage germination for one seed batch, compared to the hot water treatment only.
- Treatment with Jet 5 (peroxyacetic acid) under a range of conditions increased percentage seed germination, with best results achieved when a 16 hour pre-soak in water was followed by a 1 hour soak in 2% Jet 5.
- Jet 5 cannot be developed as a commercial seed treatment, since under current legislation peroxyacetic acid (Jet 5) is approved in the UK only for use on: flower bulbs, potato tubers, disinfection of glasshouses, warehouses, and agricultural tools and equipment.

2.6 Technology transfer

- Project information was supplied by K. Green to A. Smithson of The Soil Association, for an article in '*Organic Farming*', Summer 2004.

2.7 Acknowledgements

Provision of celery seed by a commercial seed company is gratefully acknowledged.

2.8 References

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