DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS **CSG 15**

Research and Development

Final Project Report

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Project title	The economic and agronomic feasibility of organic seed production in the United Kingdom, and its subsequent quality
DEFRA project code	**OF0166**
Contractor organisation and location	Warwick HRI Wellesbourne Warwicks CV35 9EF
Total DEFRA project costs	£ 230,209
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Executive summary (maximum 2 sides A4)

The agriculture and horticulture industries have moved ahead in leaps and bounds since the Second World War in terms of crop yields and quality, this being due in no small amount to improvements in plant breeding and seed technologies. Farmers and growers expect to be supplied with quality seed, in terms of vigour and health, of high yielding varieties, in order to satisfy their markets. During the mid to late 1990's, interest sharply increased in the production of organic crops and many current techniques, particularly the use of pesticides, became questioned by those promoting organic principles. The promoters of organic production also insisted that organically produced seed had to be used and this view created a lot of debate across the entire industry. This is now enshrined in EC legislation (directive2092/91) which requires that organically produced seed must be used for organic crop production, albeit a derogation is in place that allows the use of conventionally produced seeds where organic ones are not available.

For many farmers and growers, a move to organic production presents major challenges, particularly the fact that modern consumers demand good quality, pest and blemish free products and there are concerns over meeting these requirements without plant protection products. However the issues regarding the use of organic seeds could yet be a stumbling block, as growers and the seed trade have reservations about using and producing them for four major reasons:

1) The availability of a wide range of organic varieties appropriate to all year round crop scheduling, and differing production techniques and markets
2) The impact of derogation on managing the supply and demand for organic seed

3) The technical issues of organic seed production
4) Maintaining high standards of seed quality, hygiene and vigour.

Three biennial crops; parsnips, winter cauliflower, and bulb onions and a small range of annual crops including lettuces, runner beans, spinach, broccoli were grown for seed production. All the crops were grown under a Spanish “Haygrove” tunnel. These relatively cheap structures allow good ventilation whilst offering protection against wet weather. All the crops were grown following organic protocols.

Seed yields were recorded, and comparisons with disease contamination, germination and vigour were made against seed of the same variety produced conventionally by the collaborating seed company. Yields were unpredictable for some crops in the early stages of the project, but this problem was overcome as techniques were better understood and more experience gained. Seed quality was generally very good for most crops, and few problems were encountered with seed borne diseases for most crops. High levels of seed surface contamination with saprophytic fungi (*Penicillium and Cladosporium*) may have masked the presence of other fungi. Where equivalent comparisons with conventional seedlots could be tested for disease and vigour differences were small. However, major problems were encountered with bulb onion seed production as neck rot resulted in loss of stock material (around 50% of bulbs were lost). Hot water treatments were used in this project and were found to be successful against a range of pathogens on infected onion seed. More research into organic seed treating is advocated.

The project has shown that on a small scale at least, good quality organic seed can be produced under relatively inexpensive polythene tunnels. The yields attained can be as good as those from conventional production, but there are without doubt greater risks involved. It is suggested that should diseases or pests become rampant then their control will be difficult. This project has shown that crops like onions are extremely difficult to produce, and that neck rot in particular will be a problem for the seed producer and grower. The use of tunnels is strongly supported; they can keep crops dry at harvest, they do not necessarily encourage disease build up and natural predator populations can be built up in and around them.

It can be summed up that

1) Organic seed production was found to feasible, but higher risk than conventional production

2) Seed quality differences were small

3) Costs in terms of management input were high

4) Neck rot (*Botrytis allii)* on bulb onions was, and is likely to remain, a persistent problem

5) Hot water treatment was found to be satisfactory for the small volumes of seed treated. Urgent attention is needed to identify other more consistent methods than this which will satisfy Organic protocols.

Scientific report (maximum 20 sides A4)

INTRODUCTION

The agriculture and horticulture industries have moved ahead in leaps and bounds since the Second World War in terms of crop yields and quality, this being due in no small amount to improvements in plant breeding and seed technologies. Farmers and growers expect to be supplied with quality seed, in terms of vigour and health, of high yielding varieties, in order to satisfy their markets. During the mid to late 1990’s, interest sharply increased in the production of organic crops and many current techniques, particularly the use of pesticides, became questioned by those promoting organic principles. The promoters of organic production also insisted that organically produced seed also had to be used and this view created a lot of debate in the entire industry. This is now enshrined in EC legislation (directive2092/91) which requires that organically produced seed must be used for organic crop production

For many farmers and growers, a move to organic production presents major challenges, particularly the fact that modern consumers demand good quality, pest and blemish free products and there are concerns over meeting these requirements without plant protection products. However the issues regarding the use of organic seeds could yet be a stumbling block, as growers and the seed trade have reservations about using and producing them for four major reasons:

5) The availability of a wide range of organic varieties appropriate to all year round crop scheduling, and differing production techniques and markets
6) The impact of derogation on supply and demand for organic seed,
7) The technical issues of organic seed production
8) Maintaining high standards of seed quality, hygiene and vigour

Organic farming principles have suggested that organically produced seeds be used wherever possible, for organic crop production. However it was recognised early that there simply was not sufficient availability of organically produced seed for this to happen. Therefore a derogation has been put in place, which is due to expire on the 31st December 2003, allowing farmers and growers the option of using conventionally produced seed, treated or untreated, provided approval for use has been granted or where organically produced seedlots are not available. Unfortunately the existing derogation is not an incentive for either growers to use organically produced seed, or for the seed industry to produce it. This is especially problematic in field scale vegetables where a wide range of varieties is demanded for continuity of supply and the lead times for commercial seed production are very long, particularly for F1 hybrid varieties of biennial crops. Thus, both supply and demand is unclear until regulations are made clear. However, it has been suggested that the price of organic seed could be up to around three times the price of that produced normally (depending on crop/variety type); there could be no demand for them if they are too expensive.

There is a dearth of information relating specifically to the production of organic seed. A literature survey carried out in this project found nothing of any note that the industry could use. Even though many seed companies have their own in-house “trade secrets”, this indicates how much seed producers have moved on with crop production technologies. Over time expectations from growers with regard to seed quality have risen dramatically, seedsmen cannot sell low germination seedlots and because competition is tough, they are reluctant to sell lower vigour and health seeds (whether organic or not). For an industry that has striven to market high quality material for many years, producing and selling organically produced seeds that might compromise a hard won reputation is not an easy decision.

Seed producers need to supply seed of a minimum germination, otherwise they receive no payment. Seed merchants are very reluctant to supply seeds infected with any fungi or bacterium. Thus, it needs to be recognised that farmers and growers have had access to very high quality seed for many years; this has only been achieved by intensive seed crop management.

However, the production of organic seeds represents a marketing opportunity that may, or will need to be satisfied. There has been a tradition of seed production in the United Kingdom and indeed there still is a small but vibrant industry. This industry could yet capitalise in the organic market, if it had a better understanding of some of the problems of production and felt more comfortable about seed quality and vigour. This project targeted the issues relating to the production of organic vegetable seeds in the United Kingdom and its subsequent quality.

PROJECT MANAGEMENT AND DECISION MAKING

The project was run by a small group, chaired by Robin Wood (agronomist, HRI). It comprised of Brian Smith (plant breeder, HRI), Dr Bill Finch-Savage (seed physiologist, HRI), Dr Steve Roberts (bacteriologist HRI), Tony Hewitt (Vegetable Seeds Director, Elsoms Seeds), Gareth Davies (organic research worker HDRA), James Welch (organic advisor EFRC). This consortium was chosen because it offered a wide range of experience in conventional seed production, seed physiology, and seed marketing plus skills and experience with organic crop production. The group met at least twice yearly to choose experimental materials, oversee experimental design and to discuss and identify problems and develop appropriate solutions. Meetings were minuted and these can be made available if required.

Throughout the course of the project the group was represented at all the significant meetings of the UK organic seed working group to track potential changes in regulations, derogation and industry strategy.

Current Seed Production Practice in UK and choice of experimental production unit

It is confidently assumed that the bulk of vegetable seed grown in the United Kingdom is produced under protection, either in polythene tunnels or under glass, although it is recognised that some open field is used in a few crops. It was felt that if this project was to be of value to growers and the seed trade in the United Kingdom, then production had to be carried out under protection in order to have an adequate level of crop management control, to minimise crop losses and to give a reasonable guarantee of a crop return. In view of the fact that organic principles favour some sort of crop rotation and that glasshouse construction prices may prohibit growers converting to seed production, it was decided that semi-permanent polythene tunnels should be used. The group finally decided to use a Haygrove “Spanish” tunnel for the project. These tunnels are:

1) relatively cheap, thus if a technique for organic seed production can be found, then the cost of erecting structures need not necessarily be a barrier to production in the United Kingdom.
2) able to offer protection to inclement weather; the climate for seed production in the United Kingdom is adequate, but erratic summer rainfall can make seed production risky. Haygrove tunnels are designed to keep crops dry.
3) easy to move and re-site, thus if there are issues with soil borne diseases or soil fertility they can be relocated elsewhere on the nursery.
4) excellent for ventilation, which could help to reduce disease build up. The group felt that controlling diseases would be more problematical than insect pest control, so having an environment that did not encourage disease build up could be important. As the tunnels have open sides and ends, they do not facilitate temperature build up which can cause seed setting, quality and germination problems.

Set against this they are:

1) a relatively new concept in UK production, and are mainly, although not exclusively, used for soft fruit production - new management techniques might be needed.
2) because of their inherent design philosophy, they are more difficult to insect proof, if needed, than conventional polythene-tunnels.

The group took the view that if seeds were to be produced commercially under tunnels a degree of pest control could be obtained by the use of natural predators and permitted products. The use of mesh or fleece cages for crop isolation could also help prevent infestations of pests. The group also decided to sow a "wild flower strip" to encourage the build up of natural predators.

The site chosen was at HRI Wellesbourne where a six bay "Haygrove" tunnel was erected in early 2000, each bay being 8 x 40m. The groups' view was that all production techniques used for the crops, would strictly adhere to organic practices and principles, the sites would be registered for approval by, the Soil Association. If there were any issues arising that needed clarification, then advice from them would be sought. For any seed quality comparisons with conventional seed production Elsoms Seeds in Spalding, Lincolnshire undertook to make available seed samples from equivalent varieties wherever possible that were produced in the same year as the organically produced seed.

Crop production

The group decided initially to produce seeds from four different crops, three biennials and one annual. The biennials were a brassica (winter cauliflower), an allium (bulb onions) and an umbellifer (parsnip). The initial annual crop chosen was lettuce. During the course of the work, Elsoms indicated that it would be more challenging and more useful to grow a wider range of annuals, thus runner beans, coriander, spinach and salad rocket all featured in the programme.

The rationale for using the crops mentioned above is that within reason, seeds of them all will be demanded by organic growers in the United Kingdom (as they are traditional crops) and there is also a history of producing seed of them here. Thus, if there is a demand for organic vegetables, it is likely that one or more of these crops will be grown. The crop choice is important for the project inasmuch that growing these crops enabled a short rotation to be followed, another organic principle.

The crops also present a broad range of issues in production techniques and the economics of production. Thus, lettuce are annual, self pollinated, non-hybrid with a very high rate of seed multiplication, with a relatively low rate of use in crop production. Therefore seed demand per unit area of production is relatively low. Onions, by contrast, are biennial, insect pollinated; normally, but not exclusively, F1 hybrid varieties are used and the seed multiplication rate is quite low although the seeding rate in crop production is high and quite large quantities of seed are required

There are different techniques used in seed production (Ref. George 1999) but they basically revolve around:

1) "seed to seed" method where a crop is left in situ from drilling, or planting, until the seeds are harvested, or
2) "seed to plant to seed" method, where a crop is planted then lifted for selection/storage etc, then replanted in a final position for flowering and seed harvest.

In this project each method was used, but it became apparent that more difficulties were encountered when plants were lifted and moved to a final flowering position, so in due course, all the production (with the exception of parsnip) became "seed-to-seed". Lifting and moving plants (with the exception of parsnip roots) generally lead to poor brassica re-establishment. Severe onion neck rot was encountered if the onion bulbs were lifted and put into store before re-planting in the spring.

Organic Production Techniques

The project strove to use minimal inputs, and only "Soil Association" permitted products were used. Seed producers need to produce clean and "healthy seeds", and to meet this, both fungicides and insecticides are vital in their armoury. In organic situations, such a range of products will not be available. However, a wild flower border was sown around the organic tunnels at HRI Wellesbourne in order to encourage predator insects and it was felt by the steering committee that the well ventilated "Haygrove" tunnels by the nature of their design did not encourage disease build up. Only in Year 1 of the project did serious pest problems occur, after this and once the wild flower border was well established there was little incidence of pests.

Seed Production

Wherever possible, organic yields at HRI Wellesbourne were compared with like for like production under normal production techniques. In a market place that changes quickly, this was not always possible, but the management group were able to discuss yields in the light of experience and indicate how well the crops performed. In all instances organic principles were adhered to at HRI Wellesbourne for the steckling and seed production phases.

EXPERIMENTAL DESIGN

Within the project there were 3 (Years 1-3) seasons in which seed was harvested. Varieties used were as suggested by Elsoms who also provided guidance instructions on the conventional seed production of the designated varieties. Changes were incorporated in the experimental designs each year as knowledge and experience increased and in view of changing interpretations of the organic regulations. At the start of the project there were no specific guidelines as to exactly what organic seed production was; the only regulations available were those that governed food production. These provided general but few specifics when dealing with crops such as biennial vegetables which in a seed-to-plant-to-seed crop may well involve growing the plants in totally different ways. This potentially can involve a 1st year vegetative stage, a 2nd year flowering/seeding stage in two separate locations or even countries in two succeeding years, however guidance evolved and improved as the project progressed. In the case of onions it could be potentially more complex because many onion crops are grown from sets, so the question would then become: do organic onion sets have to be produced from organic seed?

The experiments in each of the 3 years is summarised below

Year 1 concentrated on production of only non hybrid varieties of four crops lettuce cv Saladin, onion Cv Balstora, parsnip (cv Arrow) and cauliflower (cv Burgh as these were likely to be the least problematic. Superimposed on these four cultivars were two different row spacings which were primarily to study weed control. Each polythene tunnel bay was split into 4 equal size plots to provide four replicate plots for each crop variety. This design allowed testing for variability within the experimental polythene tunnel unit and the effects of different row widths. Subsequently this layout was simplified in the second and third years. No significant positional variation could be identified and the narrower row widths gave significant problems with access and weed management. Also different water requirements at critical times for each crop were difficult to manage efficiently with this, theoretically more sensitive, experimental design.

See annex 1 for layout

Year 2 - Hybrid production of cauliflower, onion and parsnip was incorporated alongside the non hybrid varieties of the same crops with the addition of the annual coriander to the lettuce bay. The hybrid bay was separated from the remaining bays by insect proof mesh. This meant separate pollination with blowflies rather than relying on bee boxes and natural insect populations

See annex 2 for layout

Year 3 was largely a repetition of the second year with some minor changes made to the annual crops as indicated above.

RESULTS
SECTION 1: SEED YIELDS

One of the most important factors to take into account for breeders and seed producers is seed yield. As the project developed, the production techniques changed. In particular, it was felt that wherever possible, crops should be grown *in situ* and not lifted and moved (except for parsnips). The one major problem crop throughout the project proved to be bulb onions. The problems were primarily from neck rot caused by *botrytis allii* in storage. This disease is symptom-less in field production of bulb onions, but results in rotting in the subsequent storage of bulbs over winter. In this project storage losses of mother bulbs for seed production the following year were very high. The disease is seed transmitted and in conventional production can be controlled by a fungicidal seed dressing.
During this project, any crops that were grown in fields for lifting prior to re-planting, were grown organically. All operations in the tunnels followed organic principles.

Harvest Year 2000

Results in table 1 showed that some organic seeds can be produced in open tunnels in the United Kingdom with a degree of success, but, several production problems were encountered. Of major significance were the facts that:

1) More than 80% of the bulb onions became infected with neck rot during storage, resulting in fewer than anticipated bulbs to plant.
2) The winter cauliflowers were left outside over winter before being lifted for re-planting and suffered major pigeon damage. Following replanting they did not establish well, hence the low seed yield.
3) The poor summer and autumn weather caused problems with the lettuce, which was planted a little later than expected (cv Little Gem was initially agreed as an appropriate cultivar in management group minutes but it could not be supplied. It is early maturing and favoured by organic growers. cv Saladin was used as a substitute but is much later maturing.

However, there were several interesting and useful results:

1) Parsnip seed production went very well. Actual yields were as high as those produced in normal conditions.
2) Bulb onion seed yields from the remaining bulbs after storage were very good and as high as those in conventional practise.
3) From the two densities used for some of the crops, there seemed little difference in yield per plant.
4) Brassica aphid and then subsequently brassica pod midge caused serious loss on the cauliflower. Other than a temporary infestation by carrot aphid on the parsnip (cleared by natural predation) no other serious pest and disease problems were noted, except during onion storage.

Table 1 - Seed Yields Harvest 2000

Crop	Variety	Spacing	Number of plants	Yield (g) Total	Yield (g) Per m²
Parsnip	Arrow	0.6 x 0.6	234	6700	72.83
Parsnip	Arrow	1.2 x 0.4	200	5400	58.70
Cauliflower	Burgh	0.6 x 0.6	394	82	0.45
Onion	Balstora	0.6 x 0.3	357	3004	32.65
Onion	Balstora	1.2 x 0.2	367	2582	28.07
Lettuce	Saladin	0.6 x 0.4	360	26	0.28
Lettuce	Saladin	1.2 x 0.3	135	19	0.21

Thus from this years work, it was decided that all Brassicas would be grown as seed to seed and closer attention paid to bulb onion storage to see if something could be done regarding neck rot control. It was decided that, without any other obvious options to circumvent neck rot in onions, to grow a crop as seed to seed, i.e. the crops is grown *in situ* the whole way through. Because of time lag this method could not be used for the 2001 harvest but was instigated for the seed harvest in 2002.

Harvest Year 2001

Several changes were made to production form the previous year. The lettuces were planted earlier and the brassicas grown *in situ*. Unfortunately severe winter weather killed all the planned brassica cauliflower material. This probably would have happened whether or not the crop was organic. An annual brassica (Calabrese cv Pacifica) was planted in spring 2001as a substitute for the open-pollinated cauliflower
.
Again the organically produced onion bulbs were severely affected by neck rot in storage with almost total loss of planting material. Bulb onions of cv Balstora, produced conventionally rather than organically were brought from a separate source (no organic onions of an appropriate fertile open-pollinated variety could be located) and spring planted after discussion within the management group to avoid a total onion crop failure.

Table 2 – Seed Yield (g) Harvest 2001

			Yield (g)	
Crop	Variety	Spacing (m)	Total	Per m²
Parsnip	Arrow	0.25 x 0.8	18400	106.36
Parsnip	(Hybrid)	0.25 x 0.8	3300	68.75
Onion	Balstora	0.15 x 0.8	5800	61.05
Coriander	Filtro	0.01 x 0.8	8100	168.75
Calabrese	Pacifica	0.4 x 0.8	3439	19.88
Lettuce	Saladin	0.3 x 0.8	155	1.35

1) Crop failure for hybrid winter cauliflower
2) Onion used substitute conventionally produced bulbs.
3) The parsnip hybrid yield is of the actual hybrid and does not include seed from the pollinator. The planting ratio was 2 ms: 1 pollinator.

Harvest Year 2002

Seed harvest results for 2002 (Table 3) show the wider range of crops that were grown. To avoid any cross-pollination between similar crops, insect proof cages were erected over the hybrid cauliflower, hybrid onions and the hybrid parsnips.

Yields were disappointing for the hybrid Brassicas and onions however, all the other crops performed quite well, particularly the parsnips and the annual crops.

Table 3. Seed Yields (g) Harvest 2002

			Yield (g)	
Crop	Variety	Spacing (m)	Total	Per m²
Parsnip	Arrow	0.25 x 0.8	28550	165.03
Parsnip	Panache	0.25 x 0.8	7500	156.25
Onion	Balstora	0.12 x 0.8	1490	8.61
Onion	Hysam F1	0.12 x 0.8	152	3.17
Cauliflower	Burgh	0.4 x 0.8	6800	39.31
Cauliflower	Amadeus	0.4 x 0.8	86	1.79
Chickpea	ex WW97051	0.15 x 0.8*	5600	164.71
Coriander	Filtro	0.15 x 0.8*	1800	52.94
Rocket		0.05 x 0.8*	2755	81.03

Runner Beans	Enorma	0.3 x 0.8*	13500	397.06
Spinach	Spinnaker F1	0.15x 0.8*	8250	242.65

* crops were sown in double close spaced rows

The most consistent yields were produced from parsnip crops (irrespective of seed quality). In the three years of seed production, yields of the open pollinated variety Arrow were 65gm/m^2 (average of two densities in 2000) 106g/m^2 (2001) and 165g/m^2 (2002). Those of the hybrid were 68 and 156 gm/m^2 in 2001 and 2002.

Most of the annual crops have performed well with good yields from runner beans, coriander and spinach. However seed crops of onion and brassicas have been very inconsistent. Where hybrid seed production was tried seed yields were very low. Seed yields were better for open-pollinated varieties.

SECTION 2 SEED HEALTH

A range of seed health, seed germination and seed vigour tests were carried out on seed samples in all 3 harvest years where sufficient seed had been harvested from the crops. Equivalent conventionally produced seed from the same year of production supplied by Elsoms Seeds was also tested for comparison.

Seed health tests were carried out on the main seed-borne pathogens of each crop which were considered to be of commercial concern:

onion - neck rot caused by *Botrytis allii*

parsnip - canker caused by *Itersonilia* spp.

lettuce - lettuce mosaic virus (LMV)

brassicas - black rot caused by *Xanthomonas campestris* pv. *campestris* (*Xcc*)

Methods

Onions/neck rot

Onion seeds were tested for the presence of *B. allii* by direct plating of both un-treated and surface-sterilised seeds on PLYSE (prune extract, yeast, lactose, streptomycin, erythromycin) agar following a method described by Maude and Presley (1977).

Seeds were surface sterilised by immersion (with agitation for the first 30 sec) in a solution of sodium isothiocyanate containing 3% available chlorine (prepared using Presept™x tablets according to the manufacturer's instructions). Seeds were then re-dried by spreading out on sterile Whatman filter paper in a biological safety cabinet.

Seeds were placed in a grid pattern on the surface of PLYSE agar plates (9cm Petri dishes), 25 seeds per plate using sterile forceps. Forceps were sterilised between each sub-sample of 25 seeds. Three hundred un-treated and three hundred surface sterilised seeds were tested from each seed lot. Plates were incubated at 21°C for 7 d and then each seed was examined for the presence of *B. allii* using a low-power microscope.

B. allii has characteristic conidiophores, which appear silver-white when lit from above and are carried in small bunches above the surface of the mycelium. The conidiophores of *B. cinerea* look very similar, but the mycelium is less compact and growth is more rapid than *B. allii*. The numbers of infested seeds were recorded and the identity of suspected colonies of *B. allii* was confirmed following sub-culture to plates of PLYSE agar by aseptically transferring a small piece of the leading edge or a few conidiophores with a sterile needle (under a low powered microscope). A known isolate of *B. allii* was included in each test

***Parsnips/*Itersonilia**

There is no 'standard' method in general use for the detection of *Itersonilia* in parsnips, therefore the method evolved to some extent during the project. Both un-treated and surface-sterilised parsnip seeds were tested for the presence of *Itersonilia* using a method that relies on indirect detection of blastospores.

Parsnip seeds were surface sterilised by immersing (for 30 seconds) in a solution of sodium isothiocyanate containing 3% available chlorine prepared in the same way as for onions. A number of different variations on the basic method were used and compared. Seeds were aseptically attached to the lid of a 9 cm plastic Petri dish using either petroleum jelly or double-sided tape which was then inverted over the surface of the agar in the dish. In the first year 2% distilled water agar (DWA) was used (12 seeds per plate); in the second year potato dextrose agar (PDA) (20 seeds per plate), malt extract agar (MEA) (5 seeds per plate), Waksman's (12 seeds per plate) and DWA (12 seeds per plate) were compared; in the third year only MEA (5 seeds per plate) was used. Plates were incubated at 20-22°C and examined at 3 d and then daily for up to 7 d for the presence of *Itersonilia*-like colonies on the agar surface. In the first year the lids were also transferred to fresh plates after 24 h. A known isolate of *Itersonilia* was included in each test.

Lettuce/ LMV testing

LMV testing was done on 20 x 100 seed sub-samples for each seed lot following a protocol based on the ISHI (International Seed Health Initiative) method. Each sub-sample of 100 seeds was germinated in a Petri dish on four layers of Whatman No. 1 filter paper, wetted with tap water. The dishes were placed in transparent sandwich boxes, in 5 stacks of 4 dishes, and incubated in darkness at 15°C for 2 d. The temperature was then increased to 20°C and lights were set to come on for 8 hours per day. Additional water was added to the Petri dishes if necessary. After 6 d (4 d with lights), the seedlings in each dish were removed and tested for the presence of LMV by ELISA.

All the seedlings from each dish were placed in a thick polythene bag, leaving the seedcoats behind in the dish. The seedlings were then macerated in the bag using a handroller. A 30 µl aliquot of extract was taken from each bag and added to 270 µl of coating buffer to give a 1:10 dilution. Samples were loaded onto the Elisa plate and incubated overnight in a cold room. The plates were then washed and a primary antibody added (Potyvirus monoclonal (Agdia Inc, Indiana, USA, Product Code CAB 27200) (1:200 dilution) and incubated for 2 hours at room temperature. Plates were then washed and anti-mouse conjugate (1:10000 dilution) (Sigma A-5153 in PBST + 0.5%BSA) added and incubated for 4 hours at room temp. Plates were then washed, substrate added, and colour development recorded using a plate reader. Appropriate positive and negative controls were included in each plate.

Brassica/Xanthomonas *(Xcc*)

Testing for *Xcc* was done on 3 x 10,000 seed sub-samples for each seedlot following the standard ISTA method (Working sheet) using FS and NSCAA media in 2001 and using the revised ISTA method (proposed rule) using FS and CS20ABN media in 2002. Sub-samples of seed were suspended in 100 ml of saline plus Tween 20 in a conical flask, which was then shaken for 5 min. Two 1 ml samples were removed and centrifuged. The flask was then shaken for a further 2.5 hours and the extract diluted. Both centrifuged and diluted extracts were plated on the two selective media. Plates were incubated at 28-30°C for 3-4 d and then examined for the presence of suspected colonies of *Xcc*. Suspected colonies were sub-cultured to plates of YDC medium and their identity confirmed by a pathogenicity test on susceptible brassica seedlings.

Hot water treatment of Onion seed

Two seed lots, an organic produced lot harvested in 2000 (OS 00 003) and a conventionally produced lot, were treated in batches of 10 g in sterile 250 ml conical flasks containing 200 ml sterile RO water in a water bath at temperatures of 23 (room temperature), 45, 50, 55 or 60°C for 15 or 30 min. Before adding the seeds, the water in the flasks was equilibrated to the same temperature as the water bath. After treatment the seeds were strained using a sterile sieve and placed on sterile filter paper in the air flow of a fume hood to dry for 24 h. Seeds were then stored in manila envelopes in a refrigerator for 2 d, then in polythene zip-lock bags until they were tested for *B. allii* and germination.

Seeds were tested for *B. allii* and fungal contamination (400 seeds for each treatment) as described previously and germination was tested according to *ISTA Rules* (432 seeds for each treatment).

Results

Where very small quantities of seed were harvested because of partial or complete crop failure, seed health testing was not feasible. Where the target pathogen was not detected the results are presented in the tables as the detection limit (P = 0.95).

Onions 2000

The organic seed lots had 0 to 0.7% seeds infected with *B. allii* and the conventionally produced seed lot had 2.0% seeds infected. Considerable problems were experienced with the organic seed due to almost 100% contamination with saprophytes (mainly *Penicillium* and *Cladosporium)* which was not effectively removed by surface sterilisation. There was also evidence that growth of *B. allii* was inhibited by the *Penicillium.* It is therefore possible that the levels of *B. allii* in the organic seed represent an underestimate of the true level of infection or alternatively that the *Penicillium* may be acting as a natural biocontrol agent.

Table 4. Summary of results for tests *Botrytis allii* on onion seed harvested in 2000.

Seed lot cv Balstora	Pre-treatment	No. seeds	% fungal contam.	% *B. allii*
OS 00002	None	300	100	<1.0
	Surface sterilised	300	93	<1.0
OS 00003	None	300	100	<1.0
	Surface sterilised	300	84	0.7
OS 00004	None	300	100	<1.0
	Surface sterilised	300	84	0.3
OS 00005	None	300	100	<1.0
	Surface sterilised	300	85	0.3
Conventional	None	275	100	1.1
	Surface sterilised	300	21	2.0

OS numbers refer to organic seed lots harvested from replicate plots from polytunnels.

Parsnips 2000

Itersonilia was not detected in any of the seed lots using DWA medium. Subsequent comparisons in the second year indicated that this medium was the least useful for detection due to the relatively high degree of overgrowth by saprophytes, therefore these results should be interpreted with some caution.

Table 5. Summary of tests for *Itersonilia* using distilled water agar medium on Parsnip seed harvested in 2000

Seed lot - cv Arrow	Treatment	No. seeds	No. *Itersonilia* colonies	% inf
OS 00006	Natural	240	0	<1.3
	Surface sterilised	240	0	<1.3
OS 00007	Natural	240	0	<1.3
	Surface sterilised	240	0	<1.3
OS 00008	Natural	240	0	<1.3
	Surface sterilised	240	0	<1.3
OS 00009	Natural	240	0	<1.3
	Surface sterilised	240	0	<1.3
Conventional	Natural	240	0	<1.3
	Surface sterilised	240	0	<1.3

OS numbers refer to organic seed lots harvested from replicate plots from polytunnels.

Lettuce 2000

There was insufficient lettuce seed available for testing.

Brassica 2000

There was insufficient brassica seed available for testing.

Onions 2001

B. allii was detected only in the non surface-sterilised conventionally produced seed. Again the relatively high levels of contamination with saprophytic fungi may have precluded detection in the organically produced seed.

Table 6. Summary of tests for *Botrytis allii* on onion seed harvested in 2001.

Seed lot cv Balstora	Pre-treatment	No. seeds	% fungal contam.	% *B. allii*
OS 01 004	None	300	*	<1.0
	Surface sterilised	300	34.7	<1.0
Conventional	None	300	*	3.6
	Surface sterilised	300	8.3	1.0

Parsnips 2001

Itersonilia was detected on MEA in two of three conventionally produced seed lots which were tested, but not on either of the organic seed lots. Testing on DWA was abandoned after examining 60 seeds (5 plates) of each lot when it became clear that this medium was much less reliable for detecting *Itersonilia* than the others. Due to the lower number of seeds per plate on MEA (5) than on the other media (12) and the lower growth rate of saprophytes, it was considered that MEA was the best medium for detection of *Itersonilia*.

Table 7. Summary of tests for *Itersonilia* using four different agar media on Parsnip seed harvested in 2001

Seed lot	MEA		PDA		Waksman's		DWA		% inf
cv Panache	Tested	Pos.	Tested	Pos	Tested	Pos	Tested	Pos	(MEA)
OS 01003A	200	0	200	0	240	0	60	0	<1.5
OS 01001B	200	0	200	0	240	0	60	0	<1.5
85299 (conv)	200	1	200	0	240	0	60	0	0.5
85309 (conv)	200	0	200	0	240	0	60	0	<1.5
85358 (conv)	200	1	200	0	240	0	60	0	0.5

MEA – malt extract agar, PDA – potato dextrose agar, DWA – distilled water agar.

Table 8. Summary of fungal contamination after 3 days in tests for *Itersonilia* using four different agar media on Parsnip seed harvested in 2001

Seed lot	MEA		PDA		Waksman's		DWA	
cv Panache	Tested	%cont	Tested	%cont	Tested	%cont	Tested	%cont
OS 01003A	200	24.0	200	12.0	240	36.7	60	8.3
OS 01001B	200	11.5	200	8.5	240	5.8	60	0.0
85299 (conv)	200	81.5	200	60.5	240	87.1	60	60.0
85309 (conv)	200	15.5	200	*	240	9.2	60	0.0
85358 (conv)	200	4.5	200	8.5	240	5.8	60	0.0

MEA – malt extract agar, PDA – potato dextrose agar, DWA – distilled water agar.

Lettuce 2001

LMV was not detected in either the organically or conventionally produced seed.

Table 9. Summary of tests for Lettuce Mosaic Virus in lettuce seed harvested in 2001.

Seed lot (cv Saladin)	No. seeds	% inf
Organic OS 01007	20 x 100	<0.15
Conventional	20 x 100	<0.15

Brassicas 2001

Xcc was not detected on either the organic or conventional produced seedlot.

Table 10. Summary of tests for *Xanthomonas campestris* pv. *campestris* on calabrese seed harvested in 2001.

Seed lot (cv Pacifica)	No. seeds	% inf
Organic OS 01006C	3 x 10,000	<0.01
Conventional	3 x 10,000	<0.01

Onions 2002

B. allii was detected on both un-treated and surface sterilised organic seed (2.0 and 2.3%) but not on the conventionally produced seed lot.

Table 11. Summary of tests for *Botrytis allii* on onion seed harvested in 2002.

Seed lot cv Balstora	Pre-treatment	No. seeds	% fungal contam.	% *B. allii*
Organic	None	300	100.0	2.0
(OS 02001)	Surface sterilised	300	99.3	2.3
Conventional	None	300	95.7	<1.0
	Surface sterilised	300	12.3	<1.0

Parsnips 2002

Table 12. Summary of tests for *Itersonilia* using malt extract agar on Parsnip seed harvested in 2002

Seed lot cv Arrow	Tested	Pos.	% inf (MEA)	contam
Organic OS 02012	400	0	<0.75	96.0
Commercial	400	0	<0.75	23.0

MEA – malt extract agar, PDA – potato dextrose agar, DWA – distilled water agar.

Lettuce 2002

Seed was not available for testing before completion of the project.

Brassicas 2002

Xcc was not detected on either the organically or conventionally produced Winter cauliflower seedlots.

Table 13. Summary of tests for *Xanthomonas campestris* on Winter cauliflower seed harvested in 2002.

Seed lot cv Burgh	No. seeds	% inf
Organic	3 x 10,000	<0.01
Conventional	3 x 10,000	<0.01

Hot water treatment of onions

The effect of the hot water treatments on levels of *B. allii* infection, fungal contamination and germination are shown in Figs. 1, 2 and 3. *B. allii* was not detected on the untreated control batch of organic seed, nor any of the hot water-treated batches, therefore only germination and fungal contamination are presented. Germination was not examined in the commercial produced seed.

In the organic seed, germination was un-affected by treatment at 55°C for 15 min or 50° for 30 min. Fungal contamination was reduced to almost nil by treatment at 55°C for either 15 or 30 min and was considerably reduced at 50°C. The two main fungal contaminants appeared to have different temperature sensitivities: most

Cladosporium contamination was removed by treatment at 45°C, and most *Penicillium* contamination was removed at 50°C (Figs. 1 and 2).

As *B. allii* was not detected in the untreated organic seed controls, the experiment was partially repeated using a conventionally produced seed lot known to be contaminated with *B. allii*. The 60°C treatment was omitted as in the tests on the organic seed germination was significantly affected. *B. allii* was detected only on the untreated controls and in batches of seed treated at room temperature. *B. allii* was not detected in seed treated at 45°C or above (Fig. 3)

Discussion

The organically produced onion and parsnip seed characteristically had much greater levels of contamination (often approaching 100%) with saprophytic fungi than the conventionally produced seed. These high levels of contamination could have masked the presence of the target pathogens, giving a false impression of the health status of negative seed lots.

B. allii was detected in organic onions seed harvested in 2000 and 2002, but not in 2001. The pathogen was also detected in the conventionally produced seed in 2000 and 2001, but not in 2002. *B. allii* causes neck rot of bulb onions during storage and is a major cause of losses in stores. The presence of *B. allii* in organic onion seed is much more problematical than in conventionally produced seeds which are routinely treated with a fungicide. The year to year variations were probably a reflection of the differing health status of the mother plants and climatic variables. For production of organic onion seed it will be vital to ensure the health status of the seed used for mother plant production and to avoid cross contamination from nearby onion crops. However, given the widespread nature of this pathogen, further control measures may be necessary.

Itersonilia, LMV and *Xcc* were not detected in any of the organically produced seed of parsnips, lettuce and brassicas respectively. It is likely that the absence of these pathogens is a result of their absence in the seed of the maternal plants and the fact that the organic seed crops were well isolated from any other crops of the same species, thereby avoiding re-infection. This suggest that the use of clean starting material and good hygiene could be sufficient to avoid problems with these pathogens in organically produced seed.

The preliminary experiment on hot water treatment suggests that *B. allii* can be reduced to below detectable levels by treatment at 45°C for 15 min, and that contamination with other fungi can be reduced by treatment at 50°C for 15 or 30 min without detrimental effects on germination. These results suggest that hot water treatment could be useful for the control of *B. allii* and other seedborne fungal pathogens and contaminants in both organic and conventional onion seeds. Further work will be necessary to test the method on a wider range of seed lots/cultivars, with different infections levels and with health testing to more stringent quality standards before the technique can be generally recommended.

SECTION 3: SEED GERMINATION AND VIGOUR

Harvested seed was tested for percentage germination and seedling vigour characteristics which are tabulated below. Where very small quantities of seed were harvested because of partial or complete crop failure no germination and vigour measurements were taken as these would have had no meaning in comparison to successful conventionally produced seed.

Seed viability was determined according to International Seed Testing Association rules (ISTA, 1999). Coriander seeds were germinated on pleated filter paper and seeds of all other species were germinated on the top of filter paper. Germination in pleated filter paper was assessed on four replicates of 100 seeds otherwise eight replicates of 50 seeds were used. The percentage of seeds in five categories were recorded at 20 ^{o}C, non-germinated seeds that were (1) infected or (2) uninfected with fungi during the test and germinated seeds that produced (3) normal, (4) abnormal or (5) infected seedlings. Percentage data were angle transformed and subjected to analyses of variance.

In addition to viability tests, the vigour of seeds from four species was estimated using slope tests (Gray and Steckel, 1983). For these tests there were 10 replicates each containing 12 seeds. The 12 seeds were placed in a line across moist filter paper. The paper was placed on perspex slopes in a rack within a tray of water. The rack held the slopes at 20 ^{o} to the vertical with the base of the paper in the water and the seed in a line some 40mm above. The trays were covered with black polyethylene and incubated in the dark at 20^{o}C. The following measurements were made: (1) regular counts were carried out to record germination time, (2) shoot and (3) root lengths were measured at the end of the test. The length of the test differed between species: onions 10 days, lettuce 7 days, parsnip 14 days, and cauliflower 9 days. Percentage germination, mean germination time and the spread (log variance of germination times) were calculated. Percentage data were angle transformed and all data were subjected to analyses of variance. These analyses were carried out on data from all seedlings. Where there were significant numbers of abnormal seedlings the analysis was also run without them, but this did not change the pattern of results in any species.

Figures from Table 14 and 15 indicate that overall in harvest year 2000 the parsnip (in particular) and onion organic seed had lower germination, poorer vigour indicators and greater variability than the equivalent conventionally produced seed. Germinations of the calabrese, lettuce and onion from 2001 see table 17) was high, whilst the parsnip was more variable. However, it should be noted that ungraded organic parsnip seed was tested; it is likely that tighter seed grading would have removed an element of poor seed, therefore lifting the overall germination of the tested lot. Indeed, both the onion and parsnip lots produced in 2001 were comparable to the conventional lots for root and shoot lengths, and for germination times.

In general for seed harvested in 2002, there was little difference in germination and vigour between production techniques, except that the organic hybrid parsnip was extremely poor (tables 19,20 and 21). It is thought that this lot suffered as the production was carried out in a cage within the tunnel. The germination time for the organic and conventional cauliflowers , and onions were similar, with the organic cauliflower having a slightly better germination than the conventional, and *vice versa* for the onions.

CONCLUSIONS AND ECONOMIC ANALYSIS

Conventional seed production is a highly complex operation, especially for hybrid cultivars of biennial crops, and it is suggested that organic seed production is even more specialised. Because there are so few plant protection options management time involved in organic seed production is much greater than that for conventional crops.It is suggested that the key difference between organic and conventional seed production is the element of risk combined with the extra management time.

The field staff at HRI Wellesbourne that carried out this project are highly competent in conventional seed production. They and the management team were surprised by the impact of the extra management load and the almost complete lack of decision support information in the public domain for organic vegetable seed production. Inevitably this extra management input and lack of basic information will result in significantly extra costs associated with organic seed production over and above conventional seed production.

The economic and agronomic feasibility of organic seed production in the United Kingdom are two separate but interlinked issues. One relies on how much the market may be prepared to pay for seed, the other on the skills of both producer and seed merchant. A high price for organic seeds will delay uptake and use of them, (unless derogations are lifted and the issue is forced), whilst consistent high yields of quality seeds would place downward pressure on financial returns to the seed producer. The entire issue is however chicken and egg, the demand for organic seeds will be low unless the derogation is lifted; the current suggestions of seed being three times the price of conventional will dampen interest from growers and they will be reluctant to pay for them, yet seed merchants will be reluctant to produce and sell organic seed unless there is a market for them.

However, before any debate can be held regarding seed prices and the state of the market, a seed producer needs to know what sort of yields are possible using organic techniques.

Potential returns

In table 22 average seed yields for open-pollinated varieties have been estimated based on yields obtained in the project allied to sound management skills and experience. These figures have been extended to what might be budgeted for on a *per* hectare basis. The expected g/m2 seed yield figure extrapolated from the projects' data was converted to kg/ha with a 10% reduction caveat to produce what is felt to be a realistic figure for a *per* ha seed yield that could be used for budgetary purposes. Also included are average figures for conventional seed production quoted from "Vegetable seed production" (George 1999), these figures are applicable to outdoor seed production in a major and appropriate world seed production region with much acquired expertise and skills). Figures are also taken from Faulkner (1983) who produced conventional seed crops at HRI Wellesbourne (NVRS) in polythene tunnels.

Table22: Expected seed yields from organic and conventional tunnel production, and conventional outdoor production.

Crop	Expected seed yield g/m2	**Budgeted organic Seed yield kg/ha******	Conventional average commercial seed yields From open field kg/ha**	Conventional seed yields from polythene tunnel productions kg/ha***
Bulb onion (seed to seed)	50	**450**	1000 (seed to bulb to seed)	380
Parsnip	100	**900**	1000	1750
Spinach	200	**1800**	800	n/a
Winter cauliflower	25	**225**	400	440
Lettuce	2*	**18***	500	450
Runner bean	250	**2225**	1000	n/a
Broccoli	20	**180**		n/a

NB

* based on yield in this project. It is recognised as being very low and commercial organic yields should be much better.

**Figures quoted from R.A.T George 1999 Vegetable Seed Production; these figures are for seed crops grown in the open field

*** G J Faulkner 1983; Maintenance Testing and Seed Production of Vegetable Stocks at the National Vegetable Research Station

**** Figures are based on expected yields from results in this project, less 10%

Expected seed yields for onion seed production seed-bulb-seed is higher than those from seed to seed

Figures from table 22 indicate what could be considered as average seed yields, from conventional and organic crops grown under polythene protection, and those from open field situations It has to be stated that the bulk of these open field crops will be grown in countries such as France and by large commercial operations and it is to be expected that protected crops will have higher yields than those without. With the exception of lettuce, nearly all of the seed yields were as good as or better than those produced conventionally. Crops which had poorer yields included the winter cauliflower and bulb onions, but it can be seen that when onions are produced from seed to seed the difference is not as great compared to seed to bulb to seed. It is suggested that the potential organic seed yield from lettuce should be much closer to that of conventional than those achieved in this project. (Personal communications with members of the seed trade indicate that there are no shortages of organic lettuce seed, suggesting that this crop is relatively easy to produce).

Therefore it seems reasonable to assume that for some species, on a small scale at least, organic seed yields can be as good as those from conventional grown crops. It remains to be seen what the consistency of yields will be on a larger commercial scale.

Seed Quality:
The seed producer a MAFF OF0154 (The production of seed for the organic sector) highlighted diseases on seeds as a major problem identified by seed companies. The authors of that report considered that the issue may not be as problematic as the trade feared because;

1) seed borne disease could be controlled by rotations in organic systems
2) rigorous testing could eliminate seed borne disease from the seed cycle
3) disease could be avoided by;
    i. the use of resistant varieties
    ii. the use of controlled environments (ie polythene tunnels)
    iii. the use of antagonistic micro-organisms
    iv. hot water treatment
    v. the use of seed grading to eliminate diseased seed.
    vi. the use of approved plant oils (e.g. pine and mint) with qualifications

The use of rotations in organic systems is strongly supported. For the conventional seed producer this may be common practice, but the use of plant protection products will enable him to make better use of limited resources. Long rotations and fertility building periods in organic seed production will ultimately be expensive as one or two years cropping will be lost. Rigorous testing and rogueing will help to eliminate seed borne diseases, but this will also be expensive, as valuable parent plant material could be lost. Farmers and growers choose varieties that their market demands, irrespective of whether they exhibit disease resistance or tolerance, although it is acknowledged that plant breeders select for these sorts of traits. Seed grading will have major limitations and will result in the producer losing yield and income. Thus, it seems pertinent to suggest that seed producers will ultimately seek means and methods to ensure that their seed is disease free, or can be treated in such a way that eliminates any loss of yield, that is if there is a problem. In the current project the occurrence of seedborne diseases in the range of crops considered was studied under objective 3 and the availability of organically allowable treatments to control them was reviewed and evaluated under objective 4.

Results from seed hygiene tests in this project indicate that on the whole, seed produced organically have as little infection as those produced conventionally, with the major exception of bulb onions. Difficulties were always encountered with bulb onion seed production; in the first two years of the project when seed was produced by the “seed to bulb to seed” method a rule of thumb was that nearly 50% of the bulbs could be lost to neck rot. Seed produced from the same stock of bulbs did not necessarily have high recorded levels of neck rot, but detection was made difficult due to high levels of seed borne saprophytic fungi. It is possible that there could be some sort of natural “bio-control” of neck rot by *Penicillium* or other saprophytes present on the seed, but this remains unproven as a safe and reliable technique. Without effective treatment of the seeds to eradicate *B. allii* no onion grower should consider using such seed. As a caveat, it is suggested that seed producers may start to find more extensive bacterial and fungal problems when seed crops are grown on a large scale, but if nursery hygiene is good and a good rotation followed as suggested in MAFF OF0154, then potential problems may be at least kept to a minimum.

Allowable treatments to control pathogens: Production and marketing of conventional seed is heavily reliant on the use of chemicals to eradicate pathogens. These chemicals are not acceptable in organic production and so alternative “allowable” treatments need to be considered. The availability and use of both chemical and non-chemical treatments to control seedborne diseases have been extensively reviewed in the literature (e.g. Neergaard, 1977; Maude, 1983, 1988, 1996). However, the desk study carried out under objective 1 at the start of the project found considerable confusion in the definition of what constituted an allowable treatment for organic seed production. This lack of clarity was greatest when considering allowable chemical treatments (e.g.

acetic acid and fruit juices) and whether the products were "natural" in origin. For example, the research workers in this project were unable to get clarity on the status of ozone as an organic seed treating method. Currently there are other projects underway in Europe examining these and other novel methods such as electron treatments which may help to provide clarity and data on their efficacy.

In addition to chemical methods there are two further categories of potentially allowable treatments, physical and biological. Most work on biological treatment (application of microorganisms) to seeds has been directed towards of the control of soil-borne organisms, but some progress has been made on their use for control of seedborne microorganisms (Maude, 1996). Research particularly relevant to the current project was the application of bacterial cells of an *Enterobacter* species to control *B. allii* on onion seeds (Peach *et al.*, 1994). However, there are no products currently available for commercial use in the UK and any potential products must first undergo approval and so may not be available in the near future. Indeed this same requirement for approval, necessary for conventional chemical products, is necessary for chemical treatments that may be suitable in organic production; even "natural" products need to be approved for use. A grey area is whether approval may be circumvented by classification of the product as a growth promoter.

The acceptability of non-chemical physical treatments in organic seed production is not in question and perhaps holds the most likely solutions for the control of seedborne pathogens in the near future. The more commonly considered physical treatments include hot-water, aerated steam, dry heat and hot air. There has been a considerable literature on this topic, particularly on the use of hot water treatments (reviewed by Neergaard, 1977; Maude, 1983, 1988, 1996). Both pathogen and seed are sensitive to combinations of heat and moisture and their sensitivities differ. It is these differences which are exploited during most physical treatments. A particular aspect of hot water and some other physical treatments is that they have potential to penetrate within the seed coat and possibly deeper into the seeds to kill pathogens. However, seed damage, particularly in older seeds of reduced vigour is likely (Baker, 1972). As seedborne bacteria generally have a higher thermal death than fungi even more damage is likely to the seed when trying to control bacteria (Ralph, 1977). Hot water treatments have been developed for a range of pathogens by a large number of researchers, some of which have been listed by Maude (1996).

Efficacy is an issue with all potentially allowable treatments. With conventional chemicals a very high level of control is possible, but even then complete eradication of seedborne pathogens is not possible (Maude, 1996). The situation with allowable treatments is likely to be worse. However, what is required of eradicative seed treatments is that the number of infective seeds that remain after treatment is below the threshold necessary to cause disease outbreaks of commercial significance (Maude, 1996). Summary comparisons of the effectiveness of conventional and hot water treatments to control a range of pathogens compared to the level of control needed to achieve minimum tolerance levels have been made by Maude (1983, 1988). These show that in both cases the control varies and does not always achieve the minimum tolerance levels. Further consideration of this aspect of seed treatment is beyond the scope of this project except to say that studies on, and decisions about, the efficacy of allowable treatments must take this approach into account.

A further consideration is that many of the potentially allowable treatments in organic vegetable seed production, not least hot water treatment, can adversely affect physiological seed quality resulting in reduced viability and vigour. Much of this problem may be avoided by optimisation of the seed treatment protocol. However, this is not simple as the differences in sensitivity that are exploited in physical treatments exist not only among species (both crop and pathogen), but also among different cultivars and seed lots. Knowledge of the physiological factors determining these differences is lacking and optimisation of physical treatments and greater understanding of such factors is required. There are several approaches to reducing seed damage that either prepare the seed for treatment or allow repair/improvement of seed after treatment such pre-drying and seed priming respectively. In the development of allowable treatments to control seedborne infection it is therefore necessary to consider both the seed physiology and pathology when optimising treatments.

In the present work the only pathogen identified on the organic seed crops produced was *B. allii* responsible for neck rot in onions. Organically produced onion seed can be as healthy as those produced conventionally for many crops, but until reliable and satisfactory organically approved methods are shown for neck rot control then serious question marks need to be raised about the feasibility of producing and then growing with clean organic bulb onion seed. After reviewing the range of treatments currently allowable in organic vegetable production and the lack of clarity in the use of chemical treatments, physical seed treatments were the obvious choice in the present project. As described above hot water treatments can be effective in the control of seedborne fungal diseases and so were evaluated here. The preliminary experiment on hot water treatment suggests that *B. allii* can be reduced to below detectable levels by treatment at 45°C for 15 min, and that contamination with other fungi (e.g. *Cladosporium* and *Penicillium*) can be reduced by treatment at 50°C for 15 or 30 min without detrimental effects on germination. These results suggest that hot water treatment could be useful for the control of *B. allii* and other seedborne fungal pathogens and contaminants and shows the potential for non-chemical treatment of both organic and conventional produced onion seeds. As suggested above, further work will be necessary to test the method on a wider range of seed lots/cultivars, with different infections levels and with health testing to more stringent quality standards before the technique can be generally recommended.

Within the scope of this project it was not possible to perform a range of other “organic seed treatments” and test their efficacies, but it is clear that at European Union level serious thought needs to be given to this subject; failure to find a range of effective seed treatments and to determine minimum infections levels so that they can be correctly evaluated will hinder the production and marketing of organic seeds.

Seed viability and vigour: Viability and vigour are further aspects of seed quality that needs to be considered to asses seedlot performance. Laboratory germination and “module tray tests” are used by seed merchants to find out germinations of seed batches. Most vegetable crops have minimum germinations, below which seed cannot be sold. If a producer has a seedlot that does not meet minimum standards, all need not be lost; further seed grading by size, or density can be used to sub-divide lots and remove poorer germination grades or sizes. These same practices can also be used to improve the quality of seed lots that are already above the minimum standards. By and large in this project, all the organic lots produced were “un-graded” and as such it is likely that germinations could have been improved by further grading or sizing. For a small project such as this, it is impossible to analyze all permutations relating to the quality and germination of lots produced. Early data from the project showed that organic seeds, particularly the onion and parsnip, had poorer vigour indicators and had lower germinations than conventional ones. However, the organic seed was ungraded whereas the conventional seed had passed through some seed cleaning protocols within the seed company. Later field trials held by Elsoms Seeds in 2002 demonstrated that that there was no real difference in performance on adjacent plots between organic parsnip seedlots produced on this project and conventionally produced seedlots. It is suggested that for most crops the issue of seed vigour is one to be concerned about assuming that seed sold meets the minimum germination requirements. There may be issues with low vigour seedlots particularly with direct drilled crops, such as parsnips. Further work is required to determine how much seed germination and vigour of organic seedlots can be improved by standard seed cleaning and grading protocols commonly used within seed companies.

Economic viabilty

It is difficult to give a true picture on the economic viability of organic seed in the United Kingdom, but there are some key indicators

1) A small valuable seed industry exists in the United Kingdom. Whilst most bulk scale productions take place in countries with better weather and or cheaper labour, niche market productions are carried out here; for example winter cauliflower in Cornwall and Kent.
2) Some productions take place in the open field, but the majority of vegetable seed will be produced with some form of protection; for example polythene tunnels.

3) At present, organic seeds represent a niche market. Their supply and demand are linked to the current derogation, and the success or failure of organic production. Should the derogation remain in place then it may be that most growers choose to use untreated conventionally produced seed, if the derogation is removed, then organic growers will have to buy organic seed, thus strengthening the seed production market.

The project has shown that on a small scale at least, good quality organic seed can be produced under relatively inexpensive polythene tunnels. The yields attained can be as good as those from conventional production, but there are without doubt greater risks involved. It is suggested that should diseases or pests become rampant then their control will be difficult. This project has shown that crops like onions are extremely difficult to produce and that neck rot in particular will be a problem for the seeds producer and grower. The use of tunnels is strongly supported; they can keep crops dry at harvest, they do not necessarily encourage disease build up and natural predator populations can be built up in and around them.

Organic protocols suggest also that fertility building periods are used in rotations. Whilst this is a sensible proposal, it will mean that the seed producer will have areas that he cannot harvest, which will reduce his income and/or increase the cost of production.

On small to medium scale, the “Haygrove” or Spanish type tunnels used in this project would cost around £20,000/ha. A possible organic seed yield of 225kg/ha of cauliflower seed, at around conventional prices of £100/kg would indicate a poor return on investment, albeit the tunnel will have 5-10 year depreciation period. The same yield at £150/kg would represent better value for the seed producer. At the moment, small quantities only are demanded by the seed trade as the organic market is still in its infancy, so it may be possible for the seed producer to raise his prices higher. The current price that growers pay for organic vegetable seeds is around three times that for conventional and it is proposed that if this ratio is carried through to the producer, then organic seed production, whilst the market is still small, may be economically and technically possible in the United Kingdom, but not for the faint hearted.

Should the organic market in the United Kingdom remain small, it is suggested that the price of such seed will be high. As such mainstream seed producers may not take the risk to produce small quantities of seed thus allowing a high-value small scale industry to capitalise. If the organic seed market becomes larger, then the production of organic seeds in the United Kingdom will rely on growers that are able to capitalise on experience and their use of innovative organic techniques only, more favourable climates for seed production overseas will always help to lower costs of production.

References:

Baker KF. 1972. Seed pathology. In: Kozlowski, TT (ed). *Seed Biology*, Vol.2. Academic Press, New York, pp. 317-416.

Faulkner GJ. 1983. Maintenance, testing and seed production of vegetable stocks at the National Vegetable Research Station. Wellesbourne: Vegetable Research Trust, 62p.

George RAT. 1999 Vegetable seed production. New York: CAB International.

Gray D, Steckel JRA. 1983. A comparison of methods for evaluating seed quality in carrots (*Daucus* carota). *Annals of Applied Biology* **103**, 327-34.

ISTA (International Seed Testing Association).1999. International rules for seed testing. *Seed Science and Technology* 27 supplement.

Maude RB. 1983. Eradicative seed treatments. *Seed Science and Technology* **11**, 907-920.

Maude RB. 1988. Seed and treatments for the production of healthy vegetables. In: Rudd-Jones, D and Langton, FA. (eds) *Healthy Planting Material: Strategies and Technologies.* BCPC Monograph NO.33. BCPC Publications, Thornton Heath, UK, pp. 81-91.

Maude RB. 1996. Seedborns Diseases and Their Control: Principles and Practice. Wallingford: CAB International.

Maude RB, Presley AH. 1977. Neck rot (*Botrytis allii*) of bulb onions. I. Seed-borne infection and its relationship to the disease in the onion crop. *Annals of Applied Biology* **86**, 163-80.

Peach L, Maude RB, PetchGM. 1994. Biocontrol of *Botrytis allii* using an antagonistic bacterium. In: Martin, TJ (ed) *Seed Treatment: Progress and Prospects.* BCPC Monograph No. 57. BCPC Publications, Farnham, UK, pp 345-350.

Neergaard P. 1977. Seed Pathology. Vol 1. Macmillan, London, UK.

Ralph W. 1977. Problems in testing and control of seed-borne bacterial pathogens: a critical evaluation. *Seed Science and Technology* **5**, 735-752.