Table 4 Factors involved with decisions on seed treatment

Factor type	Specific factors
Key factors	Cost Date of harvest Disease presence on seed from which crop was grown Historic disease prevalence Late harvest Level of soil contamination Mechanical damage Previous fungicide applications Ultimate market for variety Value of crop Variety susceptibility/resistance Visible disease on seed
Factors from field in which seed was grown	Known soil contamination by pathogen Level of volunteers Short rotation Weather/soil conditions at harvest
Storage factors	Availability of drying facilities/ventilation after harvest Effectiveness of seed treatment application Environmental issues Grading damage Health and safety issues Length of storage Level of store hygiene Presence of condensation Presence of sprouting
Non-rational factors	Consistency of seed production Market requirement to treat Pride Protocol requirements Reassurance/insurance

Conclusion

Reacting to a changing environment requires a flexible approach. However, such flexibility must fit into a practical context. Whilst striving for control using non-chemical measures represents the most desirable way forward, this requires an attention to detail that may not always be possible. In addition, it is not yet possible to be fully confident about disease risk and even in the best managed units, disease problems can occur. Having facilities such as positive ventilation can reduce disease risk considerably but the flexibility of approach required in a changing environment will mean that seed tuber treatment will always be necessary as a last resort.

Experience in the potato industry in the last two decades has indicated that change will continue to be a feature and pressure on price and quality will continue unabated. Whilst low profit margins in seed potato production detract from investment, there is a need for growers to invest in equipment (such as good quality storage facilities) that will reduce the risk of disease development. Increasing the probability of success by considering all the factors that may impinge on tuber disease forms a major part of disease control. Thus planning ahead is a key requirement for reducing risk: proper prior preparation produces perfect potatoes.

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Seed quality development

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Summary

This paper considers when during seed development and maturation seeds attain their maximum quality – and so the best point at which to harvest seed crops, the effect of environment thereon, and the potential for improving seed quality *ex planta*.

Introduction

High-quality seed are able to 'escape' hostile seed-bed environments by germinating and emerging rapidly and in very good number, and then establishing crop canopies rapidly that capture solar radiation and thereby outcompete weeds.

In the wild, the survival of a plant species is often based on the production of a very large number of seeds to ensure the subsequent development to maturity of comparatively few plants: within-population variability, for example in the degree of seed dormancy, is often a major factor in wild species' survival strategies. In agriculture, horticulture and forestry, however, the objective of commercial growers when sowing every single seed is to produce a seedling that will emerge and subsequently establish as a healthy plant that will subsequently contribute to a uniform, high-yielding crop that can be harvested in a timely manner. This paper considers the development of seed quality within seed populations rather than just the individual seed. My starting point is a quote from William Shakespeare: '*Be not afraid of greatness: some are born great, some achieve greatness and some have greatness thrust upon them.*' (*Twelfth Night*, Act II, Scene V). My principal focus is 'when' within seed development and maturation do seeds '*have greatness thrust upon them*', the effect of environment thereon, and the extent to which seed producers can manipulate aspects of what otherwise might be deemed a natural process in order to produce consistently high quality seed lots.

Seed weight and moisture content

After pollination, a period of histo-differentiation within the developing seeds is followed by reserve accumulation. Visually, fruit enlargement is followed by seed enlargement, whereby a high proportion of the early mass (and bulk) of the seed is water. Much of this water is then progressively replaced by assimilates, typically from current photosynthesis combined with the remobilisation of reserves to the seed. At the end of reserve accumulation, vascular detachment occurs. In agronomic terms, the factors that can influence the potential yield of a seed crop have no further influence beyond this point – because no more assimilates can be deposited within the seeds. For this reason, the end of seed filling was termed physiological maturity by agronomists (Shaw & Loomis, 1951). In some species, such as the cereals, legumes and brassicas, seed moisture contents then decline substantially thereafter until they approach

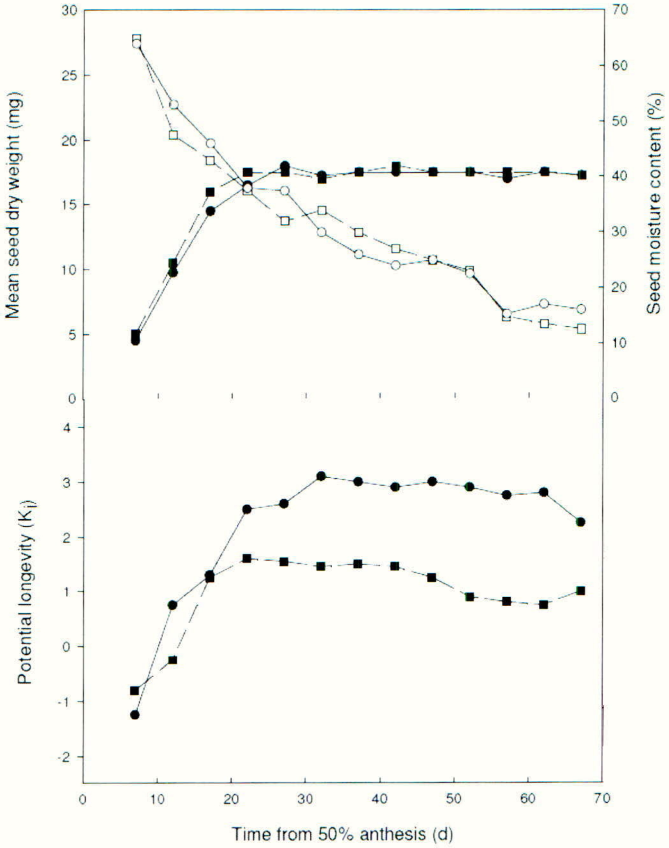

Figure 1 Changes in mean seed dry weight (solid symbols, upper figure), moisture content (open symbols, upper figure), and potential longevity in air-dry seed storage (solid symbols, lower figure; constant K_i of the seed viability equation) during the development and maturation of seeds of the *japonica* rice cultivar Taipei 309 in controlled environments of 28/20°C (circles) or 32/24°C (squares). (Redrawn from Ellis *et al.*, 1993.)

equilibrium with ambient relative humidity, whereas in species with fleshy fruits the fruit structure delays seed moisture content decline appreciably.

The upper diagram in Figure 1 provides an example of the trends for both the moisture content and the dry weight of developing and maturing seeds of a cereal. In both seed production environments in this particular case, seed-filling ended around 20 days after anthesis.

Ability to germinate, to tolerate desiccation, and to survive *ex planta*

In the context of harvesting seeds that can then be stored to subsequently establish a crop, the following phasing occurs: developing seeds first develop the ability to germinate (provided investigators are able to break their dormancy); they then become desiccation tolerant (in those species that are desiccation tolerant); and their quality (in particular their potential to survive subsequent air-dry conditions, see below) then improves further. These three phases are rather more spread out across seed development and maturation in the temperate cereals than is the case in the grain legumes, in which all three phases tend to occur comparatively close to each other and quite late on.

A belief had developed that improvement in seed quality terminated at the end of the seed-filing period, that seeds then began to age and so deteriorate thereafter, and consequently maximum seed quality coincides with physiological maturity (Harrington, 1972). However, detailed research across a wide range of cultivated (agriculture, horticulture and forestry) and wild species in normal production environments has now shown that view to be largely incorrect. Rather, seed quality continues to improve for a considerable period beyond the end of the seed-filling phase (e.g. Demir & Ellis, 1992a, 1992b, 1993; Ellis & Pieta-Filho, 1992; Ellis *et al.*, 1993; Hay & Probert, 1995; Hong & Ellis, 1992; Hong *et al.*, 1993; Kameswara Rao *et al.*, 1991; Pieta Filho & Ellis, 1991a; Zanakis *et al.*, 1994). In crops such as the cereals and grain legumes, maximum quality tends to occur in most environments close to the stage that farmers would recognise as harvest maturity. Accordingly, while the term physiological maturity may be an appropriate term for agronomists, it is a misleading and so an unhelpful term in seed production. The end of the seed-filling period is now described more simply as mass maturity (Ellis & Pieta Filho, 1992).

The solid circles in the lower diagram in Figure 1 provide an example in a *japonica* rice, whereby one estimate of seed quality (an estimate of the potential longevity of the seed in subsequent air dry storage) continued to improve until 32 days after anthesis, some 12 days after mass maturity, when seed moisture content had declined to about 35%, and then remained stable for a further 20–30 days or so.

Some will question the estimate of subsequent seed storage life as an indicator of seed quality. Since there is often a long period between seed harvest and sowing, often considerable in the case of vegetable seeds, potential seed longevity is one seed quality characteristic of direct concern to both seedsmen and growers. Potential seed longevity is also an accurate, and quite sensitive, indicator of other aspects of seed quality, including emergence ability. Hence, when other sensitive measures of seed quality have also been used, similar conclusions have been drawn that maximum quality is obtained some considerable time after mass maturity: for example, emergence ability and subsequent seedling size (Pieta Filho & Ellis, 1991b) or growth (Demir & Ellis, 1993).

Environment

The field environment can affect seed quality through its effect on seed quality development. We are especially aware in the UK of good and poor seed production years, whereby (for quality but not necessarily yield) warmer drier summers tend to be superior to cooler wetter ones. Sanhewe *et al.* (1996) provided good evidence of just such a progressive benefit to wheat seed quality from small increases in temperature (means from 14.3 to 18.4°C) from a systematic investigation in temperature-gradient tunnels.

However, at some value a further increase in the temperature of the seed production environment can become a problem rather than a benefit. The solid squares in the lower diagram in Figure 1 provide an example of the progress of seed quality development in a seed production environment that was too warm for high seed quality (but not for seed filling and so seed weight, upper diagram). Comparison of the warmer (solid squares) with the cooler environment (solid circles) shows that seed quality development was similar during the majority of the seed-filling phase, but ended around 18–22 days after anthesis and so some 10–14 or so days earlier than was the case in the cooler regime. This was a characteristic of the type of variety (a *japonica*): other types of rice showed no differences in the progress of seed quality development between the temperature regimes (Ellis *et al.*, 1993). In the warmer regime, maximum seed quality in the *japonica* was therefore first attained close to the end of the seed–filling phase. Contrary to Harrington (1972), however, no dramatic decline in seed quality was detected over the subsequent 20 days or so.

The example of the effect of environment shown in Figure 1 is extreme, in the sense that the warmer regime is beyond those that *japonica* rices normally experience. Nevertheless, it can be seen that a temperature regime that was not at all stressful for seed yield was considerably so for seed quality (solid symbols in upper and lower diagrams, respectively). In the context of anticipated climate change in summer temperatures in the UK, increases in mean temperature of 2 to 4°C during wheat seed development and maturation can be shown to improve the rate of progress of seed quality development and, despite the reduction in the overall duration of seed development and maturation also resulting from the increase in temperature, an overall benefit to seed quality at harvest (Sanhewe *et al.*, 1996). As might be expected, substantial increase in CO_2 concentration did result in heavier seeds but there was no effect on seed quality (Sanhewe *et al.*, 1996).

Economy of nature versus adaptation to different ecologies

From the above, it might be suggested that seed quality is more or less maximal at shedding in the case of wild species. This may well be true in many such species: good examples of contrasting species in which this is the case include Norway maple (Hong & Ellis, 1992) and foxglove (Hay & Probert, 1995). But of course there are examples in some ecologies where seed development continues after shedding (e.g. certain winter-flowering annuals) or at the other extreme where viviparous germination occurs prior to shedding (e.g. mangrove), or where seeds do not shed until some considerable time after seed maturity (e.g. ash).

Moreover, despite considerable selection for uniformity in crops, we may have the problem of a lack of uniformity in the progress of the development and maturation within the seed crop, such as occurs in carrot, for example.

Ex planta seed treatment

Despite these caveats, it is clear from the research to date that there is a great deal of evidence for the economy of nature in seed quality development. To what extent then is it possible for particular treatments to seeds to complement natural seed quality development? There are indeed numerous ways in which the quality of the seed lot can be improved after harvest. For example, seed cleaning can not only remove weed seeds, but can also remove broken and/or poorly filled seeds. And from the point of view of mechanical sowing, seed size can be more tightly limited to narrow bands to ensure smooth flowing through drills and precision drilling in the seed bed.

Here, I wish to mention briefly the scope of procedures which in effect mimic, extend, or resume the seed maturation process after harvest. First, there is good evidence that prematurely harvested seeds can mature *ex planta* if the subsequent environment enables the slow loss in moisture, as would have occurred on the mother plant (e.g. Hong & Ellis, 1997).

Seed priming is an interesting technique because, depending upon the circumstances, it has the potential to improve seed quality in a variety of somewhat different ways. The origin of the use of the term priming was in the context of advancing the process of germination directly and indirectly (by breaking dormancy), simply to reduce the subsequent period from sowing to seedling emergence, but in many of those reports there were sometimes problems with the subsequent desiccation tolerance of the primed seeds and/or their survival during subsequent air dry storage (Heydecker & Gibbins, 1978). The point I wish to emphasise here, however, is the potential for priming (or indeed just a moist atmosphere) and subsequent slow desiccation to enable immature seeds to resume components of the maturation process and thereby improve in quality (Butler *et al.*, 2009). Similarly, there is good evidence that some of the deterioration that aged (that is, stored for some time in poor environments) seeds have accumulated can be repaired by priming (Powell *et al.*, 2000). The ability of high moisture content conditions, provided sufficient oxygen is available and germination can be prevented, to enable the 'repair' of ageing damage is well known (Villiers & Edgcumbe, 1975; Ibrahim & Roberts, 1983).

In this context, seed quality development in fleshy-fruited species is also interesting and highly relevant. Developing and maturing tomato seeds first attained maximum seed quality at 23 days after mass maturity, and then maintained this high quality for at least a further 30–40 days while they remained within fruits on the mother plant at around 50% moisture content (Demir & Ellis 1992a). That is, they tolerated a very considerable delay to harvest without any decline in seed quality.

In conclusion, it is possible to improve seeds by treating them physically (e.g. by pelleting) as well as chemically (whether as a means of improving emergence and establishment or as a method of delivering crop protection chemicals systemically to the subsequent crop). My ambition in this communication has been to emphasise that there is much that can be done to ensure that the inherent quality of seeds, prior to any such physical or chemical treatment, can be maximised.

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The development of seed treatment products based on the new fungicide ipconazole

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Summary

Ipconazole is a new broad-spectrum fungicide belonging to the triazole group of SBI fungicides. It has activity against pathogenic fungi in the major groups of Zygomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes, and is active as a seed treatment against major seed-borne and early soil-borne pathogens on a range of crops. Ipconazole 15 ME has been developed on small grain cereals in Europe, and results presented illustrate its high activity against loose smut (*Ustilago nuda*) in barley, common bunt (*Tilletia caries*) in wheat, leaf stripe (*Pyrenophora graminea*) in barley, and seedling blights (*Fusarium* spp./*Microdochium nivale*) in wheat. Ipconazole 15 ME also demonstrates a very high level of crop selectivity, and does not adversely affect seed germination or crop emergence.

Introduction

Seed treatment continues to increase in importance as a first step in sustainable crop protection in global agriculture. Whilst this market is, in many ways, driven by the use of insecticides, there is also a need for the development of new and effective fungicides to partner the seed-treatment insecticides on a wide range of crops. It is against this background that the fungicide ipconazole was discovered and developed. Ipconazole was first patented by Kureha Chemical Corporation, and the seed treatment uses have since been licensed for global development to Chemtura Corporation. It is one of the more recent additions to the triazole group of fungicides, with an SBI demethylation (DMI) mode of action at the cytochrome P450 site. Ipconazole controls target pathogens by both protectant and curative activity as it is both a contact and systemic fungicide. It has a broad spectrum of activity relative to some earlier triazoles and controls fungal pathogens in all classes except Oomycetes. Ipconazole is very selective, being safe to seed of both monocot and dicot crops. The selectivity and efficacy profiles of ipconazole fit it for use as a seed treatment on a wide range of crops; it is already registered in Japan, Latin America and USA, and has recently received provisional or full approval in several European countries, with the UK being the RMS for the EU.

This paper describes the development of the 15 ME (microemulsion) formulation of ipconazole on wheat and barley in Europe and illustrates its activity against the major seed-borne pathogens of wheat and barley.

Materials and methods

Ipconazole (1RS,2SR,5RS;1RS,2SR,5SR)-2-(4-chlorobenzyl)-5-isopropyl-1-(1*H*-1,2,4-triazol-=1-ylmethyl) cyclopentanol (IUPAC) was discovered and developed as a rice and wheat seed treatment in Japan by Kureha Chemical Corporation (Tateishi *et al.*, 1998). Chemtura Corporation has since undertaken extensive formulation evaluation work in USA and Europe, culminating in the development of a range of stable commercial products, one of which is ipconazole 15 g/l ME (microemulsion). This product is being targeted at the cereal seed treatment market in Europe, and its formulation development and physical-chemical properties are described elsewhere in these Proceedings (see Poster: The development of an ipconazole microemulsion formulation for seed treatment. R M Clapperton, K M Littlewood). The ME technology gives a very low viscosity product which can be easily and accurately delivered to seed through existing commercial treatment equipment. Ipconazole 15 ME has a favourable toxicology profile, and is not classified.

The ipconazole ME product was applied to seed using a laboratory-scale batch treater such as the Rotogard R300, mostly pre-diluted with water. In most of the trials described, the rate of use was the label rate: 100 ml/100 kg on wheat (delivering 1.5 g a.s.) and 133 ml/100 kg on barley (delivering 2 g a.s.). Commercial seed treatment formulations of standard fungicides were applied in the same equipment for use as references in the trials.

Efficacy evaluations were done in small-plot field trials, mostly with a plot size of 1.4–2 × 6–12 m and four replications, using seed infected with the relevant pathogen. All carried natural infections except for common bunt, where spores of *Tilletia caries* were mixed with the wheat seed (2 g/kg seed) prior to chemical treatment. Control of soil-borne common bunt was assessed in trials where the plots were inoculated with a spore/sand mix prior to sowing the wheat seed. Efficacy against *Fusarium* spp. and *M. nivale* was assessed soon after emergence (crop stage BBCH 12–13) by counting numbers of emerged plants per m^2 to give a measure of seedling blight damage. Leaf stripe symptoms were assessed on barley at BBCH 51–59 by counting infected tillers per plot. Loose smut symptoms were assessed in barley by counting infected ears at BBCH 60–69. Bunt symptoms were assessed by sampling mature ears of wheat (BBCH 73–92) and counting the number of healthy and infected ears to calculate the percent infection.

Selectivity and seed safety was evaluated in field trials and in laboratory tests using healthy seed. Speed of emergence was assessed visually at BBCH 10, and then final plant emergence was assessed by counting seedlings in pairs of 0.5 or 1.0 m row lengths at five locations per plot at BBCH 12–13. Laboratory tests were conducted according to ISTA Rules in rolled paper towels, with germination being assessed after 4 and 7 days' incubation at 20°C with an 8 h photoperiod. This period was preceded by a pre-chill incubation at 5°C to break dormancy in winter cereals.

Results

Control of bunt of wheat

a) Seed-borne bunt
Trials were conducted over several seasons in Europe against soil-borne bunt, and data from six trials in the UK are shown in Table 1. Ipconazole 15 ME at the UK label rate gave 99.9–100% control and was comparable with the prothioconazole standards, and this robust level of control has been repeated across the EU.

Table 1 Untreated infection levels of seed-borne bunt and control (%) by seed treatment

Treatment	Rate g a.s. per 100 kg	E06/13-3	EC06-SAC	XAC 1475	E06/33-1	E06/33-2	E06/33-3
Untreated infection (%)	–	17.6	12.4	16.8	3.3	10.1	16.7
Ipconazole	1.5	99.9	100	100	100	100	99.6
Prothioconazole	10	99.0	100	100	–	–	–
Prothioconazole + fluoxastrobin	5.625/5.625	–	–	–	100	99.4	100

Table 2 Untreated infection levels of soil-borne bunt and control (%) by seed treatment

Treatment	Rate g a.s. per 100 kg	UK 06/1	UK 06/2	France 05/1	France 05/2	France 05/3
Untreated infection (%)	–	26.6	15.2	61.0	49.7	13.3
Ipconazole	2	99.4	99.9	99.7	99.8	100
Prothioconazole	10	99.2	99.5	–	–	–
Product A	5/5/50	–	–	100	100	–
Product B	3/2/70	–	–	–	–	88.6

Product A = Fludioxonil + difenoconazole + anthraquinone
Product B = Tebuconazole + triazoxide + imidacloprid

b) Soil-borne bunt

Infection from soil-borne spores of common bunt can be relatively important in dry autumns in France and the eastern part of the UK, and a summary of five trials carried out with ipconazole in these countries in 2005 and 2006 is given in Table 2. Infection was very successful, with symptom expression ranging from 13.3 to 61%. Ipconazole at 2 g a.s. per 100 kg seed gave excellent control of this disease: control ranged from 99.4 to 100%, and was equivalent to prothioconazole and fludioxonil/difenoconazole standards and more effective in one trial than tebuconazole/triazoxide/imidacloprid.

Control of seedling blight of wheat

The effect of *Fusarium* spp. and *M. nivale* on wheat plants and suppression of attack by seed treatments is a complex subject. The trials reported here are limited to the effects of seed-borne inocula on seedling emergence, and to the improvement in that emergence by the use of seed treatments.

Table 3 Field plot emergence counts (plants per m row) for Fusarium-infected (*M. nivale* and *Fusarium* spp.) winter wheat

Treatment	**Rate g a.s. per 100 kg**	**E06/ 05 -3R**	**E07/ 15 -2H**	**E07/ 25 -2R**	**E08/ 27 -2**	**E08/ 28 -2**
Percentage seed infection:						
M. nivale	–	39	25	21.5	31	76
Fusarium spp.	–	0	65.1	70.5	24	0
Untreated	–	8.8	7.6	6.8	9.5	2.6
Ipconazole	1.5	14.9	11.1	9.5	13.8	8.1
Carboxin/thiram	60/60	19.6	–	–	15.6	10.8
Prothioconazole + fluoxastrobin	5.63/5.63	–	12.9	11.3	–	–
LSD ($P = 0.05$)	–	–	1.38	1.48	1.88	1.88

Trials were conducted in the UK in 2006, 2007 and 2008 with a range of seed stocks infected with either pure *M. nivale* or a mixed infection of several species of *Fusarium* plus *M. nivale* as shown in Table 3. Ipconazole at 1.5 g gave good improvements in numbers of emerged plants, but its effect was less uniform than that of the best standard carboxin/thiram. There is some evidence that the activity of ipconazole is stronger against seed-borne *Fusarium* spp. than against *M. nivale*, and this is borne out by the use of ipconazole on maize where its activity against *F. moniliforme* is very good.

Control of loose smut of barley

Many trials have been carried out to prove the efficacy of ipconazole against loose smut, and data from five trials from the UK and France in 2005 and 2006 are summarised in Table 4.

Ipconazole at 2 g a.s. per 100 kg seed gave a very high and uniform level of control of this important disease, which requires systemic activity to limit the growth of mycelium from the inoculum carried inside the embryo of the seed. Ipconazole was equal to the fludioxonil/tebuconazole/cyproconazole standard and superior to prothioconazole and carboxin/thiram, and meets the level of performance needed for it to be used for retrieval in multiplication seed in the UK.

Control of leaf stripe on barley

Trials with ipconazole across the EU have shown that it does have activity against this important seed-borne pathogen, but the level of this activity is moderate compared with modern standards. This will be sufficient to obtain a partial control claim on EU labels and this will support the use on barley. Further development of a mixture of ipconazole + imazalil has therefore continued in order to provide a new seed treatment product which will give full control of leaf stripe as well as loose smut. Imazalil is a well known seed treatment fungicide

Table 4 Ear infection by loose smut in winter barley and its control (%) by seed treatment

Treatment	Rate g a.s. per 100 kg	E05/ 18 -3 UK	XAC 1475 UK	AP/10193/ CT 2 UK	AF/8396/ CT2 France	D27 ITS BS France
Untreated infection	–	2.4%	20.8/m^2	2.6%	2.9%	8.5%
Ipconazole	2	100	99.8	98.6	100	100
Tebuconazole	3	100	–	–	–	–
Carboxin/thiram	60/60	–	93.1	91.6	–	–
Prothioconazole	10	–	97.7	95.8	–	–
Fludioxonil + tebuconazole + cyproconazole + anthraquinone	2.5/ 3/ 5/ 50	–	–	–	100	100

Table 5 Percentage of normal germination of winter wheat and barley at the final assessment in paper towel tests before and after storage of seed, mean of 12 tests

Treatment	Storage period (months)					
	Wheat			Barley		
	0	6	12	0	6	12
Untreated	95.8	90.4	89.8	91.2	85.2	84.0
Ipconazole label rate	96.0	91.4	93.8	91.2	84.8	86.8
Ipconazole 2N label	95.2	91.8	94.2	90.6	83.8	87.6

for leaf stripe control, and trials in recent years with this mixture have shown that a rate of 2/5 g a.s. per 100 kg will give sufficiently high and uniform levels of control.

Seed safety and crop selectivity

These parameters are vital when considering the development of any new seed treatment, and are particularly important for a triazole fungicide, as this class of chemistry can also have plant growth regulation effects on emerging seedlings, particularly under adverse field conditions.

Ipconazole 15 ME has shown excellent crop safety on a range of cultivars of winter wheat and winter barley, and evaluation of this new fungicide at the label rate and twice the label rate in many field trials with healthy as well as infected seed has not indicated any reduction in speed of emergence nor final stand. Those field trials have included late drilling in difficult seed beds, and it seems evident that ipconazole has good crop safety under a wide range of conditions.

The excellent selectivity of ipconazole has been confirmed in laboratory seed safety tests, and typical data from rolled paper towel tests are presented in Table 5. This shows that the germination of seed treated at 2N rates and stored for up to 12 months was not adversely affected by ipconazole: the germination of untreated seed had decreased slightly over this period, as is usual, but the germination of seed treated with ipconazole is often higher than that of untreated seed.

Discussion

The broad-spectrum, systemic fungicidal activity of ipconazole, linked to its excellent seed safety, evident in early-stage evaluations, have proved to be key benefits of the products developed in Europe for cereal seed treatment.

Ipconazole 15 ME is the first in a range of products being developed by Chemtura based on ipconazole, and is being registered and introduced across Europe as Rancona™. Dose–response trials defined the use rate on wheat to be 1.5 g a.s. per 100 kg seed, and the data presented in this paper demonstrate the full control of seed-borne common bunt given by ipconazole 15 ME at this rate. This rate, equivalent to 100 ml of formulated product per 100 kg seed, has also been shown to improve crop establishment of winter wheat by giving protection against seedling blight caused by seed-borne *Fusarium* spp. and *M. nivale*. The same product but at the slightly higher rate of 2 g a.s. (133 ml of formulated product) also gives full control of soil-borne common bunt, even at high infection levels.

The use rate of ipconazole at 2 g a.s. on winter barley has given complete, or almost complete, control of loose smut, and this activity is linked with partial control of leaf stripe for the ipconazole 15 ME product.

The ipconazole 15 ME product has been shown to be very safe to wheat and barley seed even at high rates and after storage of treated seed, and it is very selective on crops in the field. Ipconazole 15 ME will therefore be a valuable addition to the range of seed treatment fungicides for small grain cereals in Europe.

This will be followed by the introduction of an ipconazole/imazalil ME product specifically for barley seed treatment and giving full control of both loose smut and leaf stripe.

Other solo ipconazole products are registered in USA, Canada and Latin America. Mixtures with co-fungicides, including metalaxyl, which expand the spectrum of ipconazole to suit crops such as maize, peanuts and soybeans, are now registered in the USA and Argentina.

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Spinosad: an effective, organic seed treatment insecticide for certain vegetable crops

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The IR-4 Project (Interregional Research Project No. 4) is a publicly funded program in the United States that assists growers of specialty crops to gain registrations for pest control products. Assistance from IR-4 is essential and necessary when the economic incentive for the registrant companies precludes the companies from obtaining the registrations themselves. This is often the case for small acreage specialty crops in the United States. The costs associated with GLP data generation and the fees required to submit a tolerance petition to the US Environmental Protection Agency are simply too high to justify the investment when the expected returns from the registration are considered. Without the assistance of the IR-4 Project, many specialty crop growers would be unable to use the newest, safest pesticides on the market. IR-4 helps growers produce an abundant, affordable and safe crop for domestic consumption and export markets.

Spinosad insecticide (formulated as Entrust® from Dow AgroSciences) is a well known and effective organic insecticide that has been registered for several years in the United States for the control of many important foliar pests. It is extremely safe and approved for use on all food commodities.

The potential for spinosad as a seed treatment in the USA first became apparent when it was tested against onion maggot (*Delia antique*) in 2001 by Cornell researchers Alan Taylor and Brian Nault. Soil drenches of chlorpyrifos, the standard control material, were far less effective in preventing seedling loss than the spinosad seed treatment. Spinosad seed treatment was also numerically superior to seed treatment with cyromazine.

Nault and Taylor repeated their onion work in 2002 and 2003 and continued to observe encouraging results. Unfortunately, Dow AgroSciences was not convinced there was commercial potential. The registrant also had very little experience with seed treatments and this exacerbated the situation. Realising the potential of this technology for onion growers, the researchers came to IR-4 for registration assistance in August 2003.

A dialog between the researchers, IR-4 and Dow AgroSciences was established, the goal being to encourage the registrant to pursue registration of spinosad as a treatment on onion and perhaps other crops.

Dow AgroSciences did agree to support the registration of spinosad against onion maggot in 2006 via a research effort coordinated by IR-4. IR-4 quickly pushed for registration on nine