A pest of particular importance in northern Germany is cabbage root fly (*Delia radicum*). As the larvae were active in October and November of each year, the assumption is made that they were the product of third-generation cabbage root fly. Trial results (primarily from Germany) are given in Table 4.

Table 2 Leaf damage caused by adult cabbage stem flea beetle (*Psylliodes chrysocephala*) assessed primarily at 1–3 true leaf stages (range 1–5 true leaves): percentage plants damaged (20 results); numbers of feeding holes per plant (11 results)

	Percentage plants damaged		Feeding holes per plant	
Treatment a.i./kg	**Mean**	**% reduction**	**Mean**	**% reduction**
Untreated	38.0	0.0	3.9	0.0
IMD&CYB 2 g+2 g	23.3	38.7	2.1	46.2
CTD&CYB 5 g+1 g	16.2	57.4	1.0	74.4

Table 3 Leaf damage caused by larvae of turnip sawfly (*Athalia rosea*) assessed primarily at 3–4 true leaf stages (range 1–7 true leaves): percentage leaf area damaged (7 results); % larval infestation (7 results)

	Percentage leaf area damage		Percentage larval infestation	
Treatment a.i./kg	**Mean**	**% reduction**	**Mean**	**% reduction**
Untreated	22.0	0.0	65.6	0.0
IMD&CYB 2 g+2 g	15.2	30.9	34.3	47.7
CTD&CYB 5 g+1 g	9.8	55.4	10.7	83.7

Table 4 Root damage caused by cabbage root fly larva *Delia radicum* (Germany, Poland) assessed primarily at 7–9 true leaf stages (range 6–10 true leaves): percentage plants damaged (9 results); root damage index (7 results)

	Percentage plants damaged		Root damage index	
Treatment a.i./kg	**Mean**	**% reduction**	**Mean**	**% reduction**
Untreated	39.7	0.0	1.3	0.0
IMD&CYB 2g+2g	30.4	23.4	0.9	30.8
CTD&CYB 5g+1g	19.7	50.4	0.6	53.8

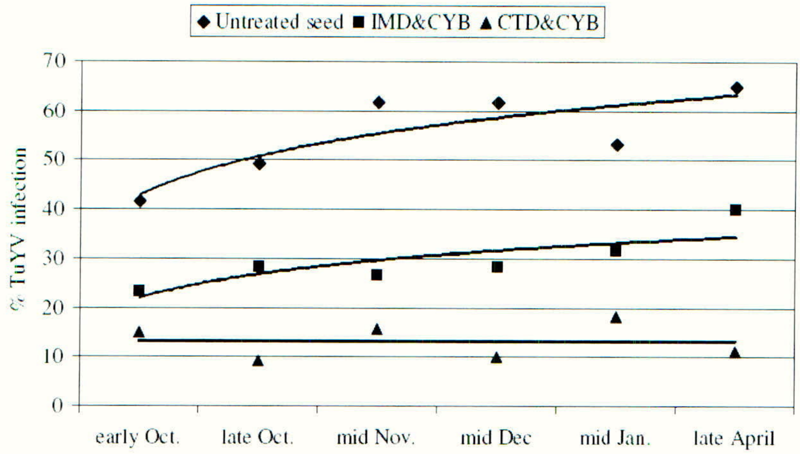

Figure 1 Seasonal development of *Turnip yellows virus* (TuYV) in oilseed rape: mean of three trials in England, 2007–08

The peach potato aphid (*M. persicae*) rarely builds up sufficient numbers in winter oilseed rape crops to cause physical damage, however it is the principal vector of TuYV. The aphid counts from UK and French trials are given in Table 5. The TuYV ELISA test results from trials in England are given in Table 6, and are split between results with infection levels above or below 85%. More detailed studies were undertaken in 2007–08 when the seasonal

Table 5 Reduction in: potato peach aphid infestation *Myzus persicae* (from UK, France) (10 results) assessed primarily at 5–7 true leaf stages (range 3–9 true leaves)

	Aphids per plant		
Treatment a.i./kg	**Mean**	**Range**	**% reduction**
Untreated	2.81	0.22–6.40	0.0
IMD&CYB 2 g+2 g	0.67	0.00–2.06	76.2
CTD&CYB 5 g+1 g	0.15	0.00–0.44	94.7

Table 6 Percentage plants infected with *Turnip yellows virus* (TuYV) where virus <85% (7 results); percentage plants infected with TuYV where virus >85% (8 results); UK trials assessed in the spring following sowing at early stem extension stage

	TuYV < 85%		TuYV > 85%	
Treatment a.i./kg	**Mean**	**% reduction**	**Mean**	**% reduction**
Untreated	44.0	0.0	96.6	0.0
IMD&CYB 2 g+2 g	19.8	55.0	83.8	13.3
CTD&CYB 5 g+1 g	10.6	75.9	71.1	26.4

Table 7 Mean crop yield from five trials where *Turnip yellows virus* (TuYV) had been confirmed, from UK (2005–08 harvest seasons)

	Crop yield (t/ha)		
Treatment a.i./kg	**Mean**	**Range**	**Relative**
Untreated	3.23	2.58–3.76	100.0
IMD&CYB 2 g+2 g	3.48	2.51–4.2	107.8
CTD&CYB 5 g+1 g	3.61	2.90–4.0	111.8
% TuYV	66.5	21.3–100	

development of turnip yellows virus was recorded in three trials in England at approximately monthly intervals from 3 weeks after crop emergence. The mean results are depicted in Figure 1, to which calculated trend lines have been added.

Discussion

Given the financial and agronomic importance of the oilseed rape crop in the UK and the rest of northern Europe, it is critical that the crop achieves good establishment so that it has the potential to return a good yield. Preventing or at least reducing damage from adult stages of cabbage stem flea beetle is crucial to obtaining good crop establishment. Insecticide seed treatments are the most effective method of affording that protection, as this pest can cause severe damage to the crop even before it emerges from the ground. The results given in this paper demonstrate that the clothianidin-based seed treatment improves crop establishment in the presence of soil-dwelling pests, particularly cabbage stem flea beetle, over that given by the imidacloprid-based treatment. Not only that, but the direct assessments of cabbage stem flea beetle damage, which were generally conducted some time after crop emergence counts, revealed that the clothianidin-based treatment gave greater persistence in protecting the crop.

Changes in the climate have, in the main, been notable for the warmer and drier summers which have extended into milder and longer autumns, followed by winters with fewer frosts. Conditions such as these have favoured the build-up of aphid populations (Stevens *et al.*, 2008); extended the potential for third-generation cabbage root fly to damage crops (Anon., 2004) as experienced in Germany; and resulted in damage by turnip sawfly larvae reaching economic proportions in parts of England. The clothianidin-based seed treatment gives very useful activity against both turnip sawfly and cabbage root fly which, in many instances, would have reduced the requirement for foliar insecticides to be applied to the affected crops.

The insecticide clothianidin is very effective when applied as a seed treatment in giving protection against the peach potato aphid in arable crops. To date, there have been no recorded instances of resistance in this aphid species against the neonicotinoid insecticides in northern Europe, unlike the situation with regard to the increased levels of resistance against the pyrethroid and carbamate insecticide groups (Foster & Denholm, 2008). The trials results reported demonstrate that the clothianidin-based seed treatment is particularly effective in giving protection against aphid infestation in oilseed rape. This is very important because the peach potato aphid is one of the most important vectors of turnip yellows virus, and research has shown that up to 70% of winged aphids caught in traps are carrying the virus. TuYV infections of up to 100% have been recorded in commercial crops in the UK. The presence of the virus can only be confirmed by ELISA tests, so the infection goes undetected in most commercial crops. Although visually difficult to recognise, the virus has significant effects on infected crops, such as reduction in stem height, leaf area, raceme and pod numbers, and reduction in the number of seeds per pod. Yield losses of 10–40% have been recorded (Stevens *et al.*, 2008).

The results reported in Table 6, where TuYV was less than 85% infection, demonstrated a mean reduction of over 70% from use of the clothianidin-based seed treatment, and this was reflected in yield increases (Table 7). The virus testing was initially conducted in the spring following sowing as the crops entered the stem extension phase, and it was noted that virus control from the clothianidin-based seed treatment was sometimes less effective. In an attempt to understand the dynamics of virus infection, a small number of trials were established in 2007–08, and plants were sampled at monthly intervals over the autumn and winter. Within 3 weeks of crop emergence, 40% of unprotected plants had already been infected with TuYV, and this rose to over 60% by the following January. By late April, the virus levels on unprotected plants had risen only marginally as the aphid migration had all but ceased. This was in contrast to the results reported by Stevens *et al.* (2008) for 2006–07, when the aphid migration continued until April and the TuYV level rose steadily through the early spring. It is concluded therefore that the apparently poor levels of virus control from trials with greater than 85% infection, principally in 2006–07, were due to the early spring aphid migration when the seed treatment had naturally degraded and been diluted in the growing crop.

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Smart pellet technology for safe and accurate insecticide applications

F Tetteroo, S Kofman and B Legro

Incotec Holding, Westeinde 107, 1601 BL Enkhuizen, the Netherlands

Email: frans.tetteroo@incotec.com

Summary

Application of new generation plant protection products on vegetable seeds is becoming more common. This new chemistry is of great advantage to the entire food chain. At the same time, this chemistry results in new challenges, posing increasing seed quality issues for the application companies, such as lower germination energy, germination capacity and shorter shelf life. Smart technology has been developed to prevent these problems. A non-living seed is coated with a plant protection product and sown next to a living seed, which will germinate normally and still be protected against pests and diseases. Furthermore, Smart technology is providing the plant protection industry with more options for even more optimal control of pests and diseases through seed treatments, due to the unlimited possibilities of sustained release and the addition of other active ingredients such as fertilisers or plant growth promoters.

Introduction

In the past decade, more and more sophisticated systemic plant protection products, such as the neo-nicotinoids, have been developed and successfully marketed. This new class of plant protection products is perfectly suited for use as a seed-applied treatment. Examples of such new systemic plant protection products are HortiGaucho® (Imidacloprid) and Sepresto® (Clothianidine), both from Bayer, DermaCor™ X-100 (Chlorantraniliprole) from Dupont, and Cruiser® (Thiamethoxam) from Syngenta. Next to these new developments, more traditional and existing chemistry is being reintroduced as seed treatments, such as Abamectine under the Avicta brand from Syngenta. Plants raised from seeds treated with these plant protection products will be protected against pests and/or diseases for a large part of their entire growth period. The absolute amounts of plant protection product needed to protect the crops with seed treatment against pathogenic organisms are significantly lower compared with foliar spray or soil applications. The active ingredients applied on seeds are positioned in such a way that they work more efficiently. Furthermore, seed treatment of plant protection products, instead of field application, is much safer for farmers as there will be less risk of contact with harmful chemicals.

However, for long-term protection of the crop, the dosages of these new types of plant protection product are much higher compared with traditional plant protection products (e.g. contact insecticides). For example, the rate of imidacloprid (HortiGaucho 70WS) on brassicas in the UK is 150 g per 100,000 seeds. This means that on a 200 g cauliflower seed batch with a TSW of 2 g, in total 215 g HortiGaucho 70WS.must be applied. As a consequence of such high rates, it is not unexpected that the germination characteristics of such coated seed are negatively influenced. It is often observed that these plant protection products inhibit the germination

Table 1 Effect of HortiGaucho 70WS application on the percentage of good seedlings after standard lettuce greenhouse germination test (coated seeds were stored at 20°C and 40% RH)

Treatment	Imidacloprid rate (mg/seed)	Fresh	Time (weeks) 2	4	6	8	10
Control	0	100	100	100	99	99	100
HortiGaucho	0.8	99	94	82	50	38	2

rate and the emergence of seed, which can influence the final plant stand and quality. This quality loss is not only due to the active ingredients of the plant protection product, but may also be due to the other non-active components in the formulations. The application of such high rates of plant protection product on seeds, which often are used in combination with other products, not only can affect the germination and the subsequent growth of the seedlings, but also influence the shelf life of the coated seeds. Table 1 shows a practical example of such a decrease in shelf life of lettuce seeds coated with HortiGaucho 70WS. It is generally well known that this reduced shelf life is caused not only by the plant protection product, but also due to the quality of the used lettuce seed lot and the actual germination conditions.

It is obvious that such a decrease in percentage of good plants is commercially unacceptable, and solutions must be found to solve these problems. Another limitation of conventional seed application technology is the potential pre-release and flushing of the active ingredient before it can be used by the plant. Besides limiting the period of availability of the active ingredient, this may also imply the need for an overdose of the plant protection product in order to have sufficient sustained active ingredient left in the root zone.

In this report, we will demonstrate that the so-called Smart technology can deal with all these issues. The Smart technology concept consists of a second pellet or coated seed which carries the potentially phytotoxic plant protection product – this second pellet consists of a non-germinating seed coated with the systemic pesticide. The plant protection product must have a legal registration for seed treatment. In order to comply with the regulations, the non-germinating seeds must be from the same species as on the label registration. For ease of handling, the Smart product is produced in the same manner as the standard seed-coating products. The Smart product is sown beside the standard pellet or seed. This paper demonstrates the benefits of this innovative Smart pellet technology to improve the quality of seedlings.

Materials and methods

Production of Smart pellets

Seeds of lettuce (*Lactuca sativa*) or white cabbage (*Brassica oleracea*) were killed by means of γ-rays (40 kGy). The lettuce seed batch was first pelleted according to the standard traditional pelleting procedure, using a standard 100 cm diameter pelleting pan (Vingerlings Machinefabriek bv, Rotterdam, the Netherlands). This process entailed the alternating addition of coating material and binding solution, providing pellets of a uniform shape and size (3.25–3.5 mm slot screen). Subsequently, the pellets were dried for 1.5 h at 40°C. In a fume cupboard, a coating formulation was mixed containing a plant protection product, Disco Color Red L083 (a commercially available red polymer formulation), and water. The batch of dried pellets or the raw brassica seeds were processed in a pan coater (Ramacota) according to a standard processing procedure. The coating formulation was evenly and slowly distributed over the pellets under simultaneous drying (at 55°C). In this way, the plant protection product is applied in a thin film of coating on the outside of the pellet or seed. The sustained-release Smarts were made by application of an extra coating layer containing the hydrophobic polymer polylactic acid with the same pan-coater technology. The release rate of the active ingredient was affected by increasing the rate of polymer: Smart release A had 1.4 mg polymer per seed; Smart release B had 2.0 mg/seed; and Smart release C had 2.7 mg/seed. Determination of active ingredients was done with HPLC technology.

A ThermoProduct HPLC system with reversed-phase C18 column and a UV detector was used to determine the recovery and seed-to-seed distribution of the plant protection products in the Smart products. Active ingredients of the products coated on the single seed/pellet were extracted for 2 h in a 1 ml Acetonitril solution. Per treatment, 100 single seeds/pellets were used to determine the distribution graph.

Slow-release measurements

Two replications of 100 Smart pellets were submerged in 100 ml water. At specified time intervals, 1 ml samples were taken out and the active ingredient was determined using HPLC. The slow release in the field and greenhouse were determined by collecting Smart pellets planted in the soil at specific time intervals. The remaining active ingredient was again detected using HPLC.

Field trials

All field trials were performed by the Dutch experimental station Proeftuin Zwaagdijk. They used complete randomised block designs with four replicates of 70 plants per treatment. During the entire growing season, the number of thrips (*Thrips tabaci*) on brassica or the number of aphids on lettuce were recorded. The data were statistically analysed with the GenStat software program.

Results

Germination

In order to demonstrate the effects of plant protection products on germination capacity, two examples are shown with application of Gaucho and Smart technology on lettuce (Table 2) and white cabbage (Table 3). The lettuce data are final germination counts, whereas the white cabbage data are pre-final data (7-day counts). After 14 days, all white cabbage treatments had over 95% good seedlings. These data show clearly that Gaucho application hinders the germination of white cabbage, which results in a less uniform plant stand. For lettuce, this effect was less obvious. Both tables also demonstrate clearly that the use of Smart technology does not influence the germination of both species, whereas the standard commercial SanoKote and SanoCrust seed products, in which Gaucho is applied directly onto the living seed, gave the worst results at 91 and 69.8% good plants, respectively.

Table 2 Effect of HortiGaucho 70WS application on the percentage of good seedlings of lettuce (*Lactuca sativa*) after 14 days' standard greenhouse germination test

Treatment	Imidacloprid rate (mg/seed)	Good plants	Abnormal plants	Not germinated
Raw seed	0	98	2	0
Raw seed + Smart	0.8	98	2	0
Split pill	0	98	2	0
Split pill + Smart	0.8	98	2	0
SanoKote Gaucho	0.8	91	8	1

Table 3 Effect of HortiGaucho 70WS application on the percentage of good seedlings of white cabbage (*Brassica oleracea*) after 7 days' standard greenhouse germination test

Treatment	Imidacloprid rate (mg/seed)	Good plants	Abnormal plants	Not germinated
Raw seed	0	95.7	2.2	2.2
SanoCrust Gaucho	1.5	69.8	6.2	24.2
Control Smart	1.5	83.4	12.8	4.0
Smart release A	1.5	87.1	8.6	4.4
Smart release B	1.5	94.8	2.9	2.4
Smart release C	1.5	94.5	1.8	3.7

Recovery and seed-to-seed distribution

Important quality parameters for the coating of plant protection products on seeds or pellets are the recovery of active ingredient, and the seed-to-seed distribution thereof. With the standard technologies known within the seed industry, it was noticed that both recovery and seed-to-seed distribution could be improved. Therefore intensive research has been done to develop a new application method with advanced characteristics. In Figure 1, a comparison is made between the standard traditional pan-coater technology and our advanced technology with thiamethoxam coating on lettuce. The target of 0.80 mg a.i./seed was reached with the new technology, whereas in this example with the traditional pan-coater technology, only 0.71 mg a.i./seed was established. The curves clearly show the difference in distribution of active ingredient of both coating methods. With the new technology a much more narrow distribution was achieved.

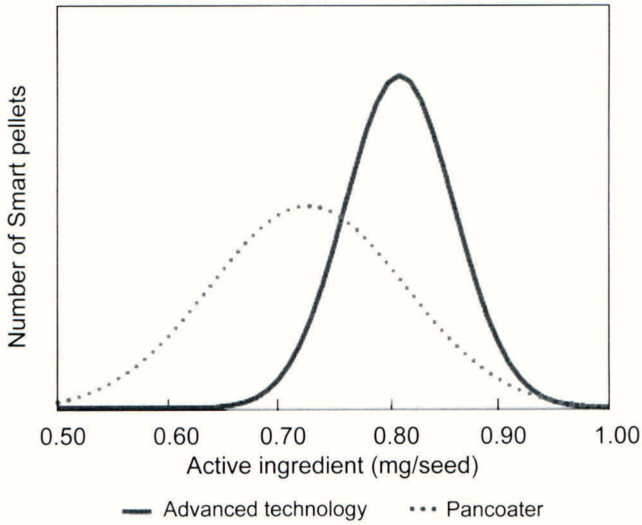

Figure 1 Cruiser® distribution on lettuce pellets coated using different coating technologies

Disease control data

Several field trials were performed in cooperation with the Proeftuin Zwaagdijk to show the efficacy of Smart technology compared with standard coating, and the commercially available drench method with Admire. Lettuce and white cabbage were used as model crops. Results with lettuce demonstrated nicely that the Smart technology gave similar control of aphids compared with standard seed treatment with HortiGaucho (data not shown). The results with white cabbage are shown in Table 4. These data demonstrate that Smart technology can control thrips as well as the standard SanoCrust coating; however, both were less effective compared with the drench. This can be explained by the different amounts of active per plant (column 2). The double Smart resulted in almost the same dosage and therefore gave the same results as the soil drench: only four thrips per five plants.

Table 4 Control of thrips on white cabbage using different application methods (mean number of thrips per five plants at different counting days)

Treatment	Imidacloprid rate (mg/seed)	8 Aug	7 Sep	13 Oct
Control	0	0.3	16	48
SanoC	1.4	0	11	23
Smart	1.4	0	7	14
Drench application*	3.5	0	8	5
Double Smart	2.8	0	11	4

*Admire was used for this treatment instead of HortiGaucho 70WS.

Sustained release of active ingredients

By increasing the amounts of polylactic acid, it was possible to create different release patterns of imidacloprid from white cabbage Smarts. Figures 2 and 3 show these release patterns in water and under field conditions. Both clearly show that increasing amounts of polymer result in slower release regardless of the conditions. Both figures also demonstrate that the release in water is much quicker compared with field conditions, where less free water is available as release medium and thus water availability is the limiting factor. Under field conditions, even after 80 days, 50–70% of the active is still not released, whereas in water only Smart release C still had 20% active ingredient remaining. These clearly different release patterns explain the germination results in Table 3. The best germination was reached with the slowest release of active ingredient. The lack of free water, causing less release of active ingredient, may play a role in the control of thrips (see Table 5). On 9 September there appeared to be an effect on the thrips, but at the final harvest no differences in thrips were found.

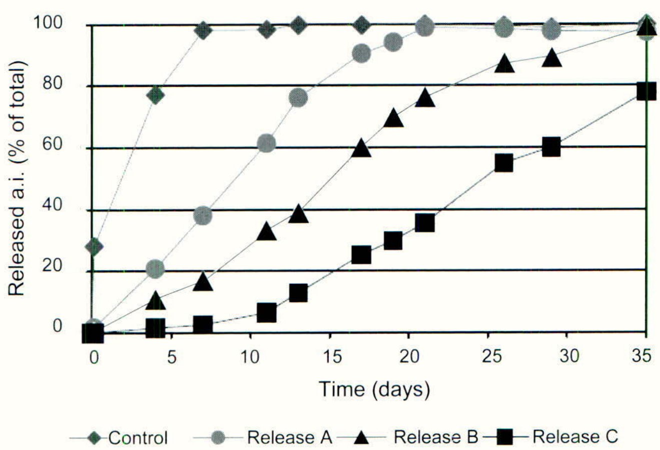

Figure 2 Release patterns in water of four different Smart objects with different release coatings

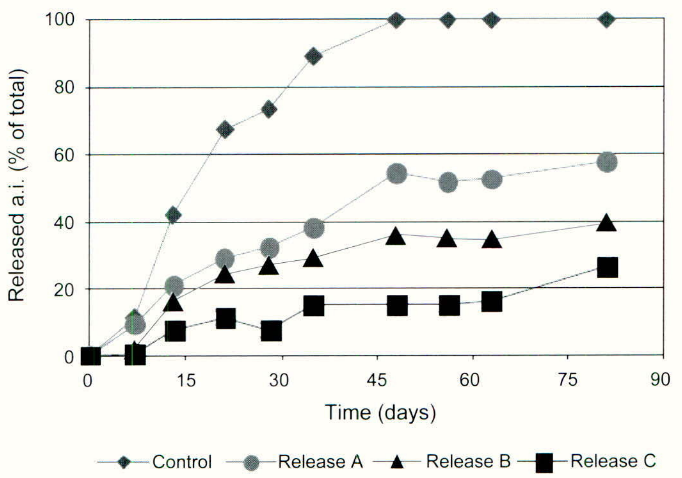

Figure 3 Release patterns under field conditions of four different Smart objects with different release coatings

Table 5 Effect of sustained-release Smart on the control of thrips in white cabbage

Treatment	Imidacloprid rate (mg/seed)	27 Jul	9 Sep	13 Oct
Raw seed	0	5.0	19.3	18.3
SanoCrust Gaucho	1.5	5.3	12.5	19.8
Control Smart	1.5	4.3	9.5	16.0
Smart Slow release A	1.5	4.8	11.3	25.0
Smart Slow release B	1.5	3.0	13.8	17.0
Smart Slow release C	1.5	3.8	7.0	12.5

Discussion and conclusion

Controlling pests and diseases becomes more and more important in the production of crops in order to gain the highest yields. The use of plant protection products is a necessity to reach this goal. Seed treatment is the most effective application method, because the active ingredients are located where they have to perform their action. Smart technology is a very elegant addition to the seed treatment arena. The accurate recovery and the uniform seed-to-seed distribution of active ingredient is of high quality. Smart technology is better suited to making more uniform pellets with more equal surfaces. This report has shown that Smart technology prevents the loss of seed quality and still results in the same control of pests and diseases. It furthermore provides additional options to create specific sustained release patterns that are not possible through standard seed treatments. This accurate application method can also be used for other actives, such as nutrients or plant growth promoters.

Formula M – innovative formulation technology for cereal seed treatments

L Mittermeier[1], B Hussherr[1], S Baum[2] and F Guyon[2]

[1]*Syngenta Crop Protection AG, Schwarzwaldallee 215, CH-4002 Basle, Switzerland;*
[2]*Syngenta Crop Protection Münchwilen AG, Breitenloh 5, CH-4333Münchwilen, Switzerland*

Email: ludwig.mittermeier@syngenta.com

Summary

The use of seed treatment products in cereals has been a standard practice over many years, as it assures control of diseases or pests that either cannot be controlled otherwise, or cause risk and damage at the early development stages of the cereal crop. In addition, seed treatment offers a targeted application method of agrochemicals. Today almost all seed-treatment products are formulated as flowable suspension concentrate (FS formulation). In contrast to the previously used solvent-based products, FS formulations reduce flowability of treated seed immediately after application, and also can cause more problems with stickiness to the seed treater and higher risk of dust-off. The Formula M formulation technology developed by Syngenta now offers some significant improvement of FS seed treatment formulations for cereals.

Methods

A specific funnel that measures the seed flow relative to untreated seeds was developed to test seed flow. The funnel is equipped with a pneumatic closable lid connected with a timer. The treated seeds are placed in the funnel, then the lid opens for a given time (e.g. 2 seconds) and the quantity of the seeds that flow out is measured. These measurements can be taken at different times, directly after the treatment, after drying or after storage.

The Heubach test was used to measure dust-off. The treated seeds are mechanically stressed in a rotating chamber for a given time, which generates abrasion. A pre-defined airflow stream carries the generated dust to be collected on a filter and quantified by weight. Only the fine dust was considered for the Formula M technology.

Formulation characteristics

In the past, the seed treatment formulations were often based on organic solvents, and the previously mentioned requirements were met. Nowadays, seed treatment formulations are mostly water-based, with the advantage of higher safety for the environment, improved seed safety and improved operator exposure risk. However, this generally has disadvantages, including less uniformity of seed treatment (resulting in a less pleasing appearance of treated seeds and poor distribution of the product between seeds within a seed batch), significant reduction of flowability of treated seeds, and limited adherence of product on the seeds (higher dust-off).

As a result of this not completely satisfactory situation, Syngenta started a development program with the goal of identifying and establishing a solution that offers the same advantages as the conventional water-based product, but overcomes the limitations mentioned above. A wide range of chemistries were tested, including oils, polymers, surfactants, waxes and carriers. These had to provide a positive impact on the application properties while being compatible with the water-based suspensions. Finally, a system was identified and established which provides the targeted benefits:

- better coverage and attractive appearance of the seeds
- better flowability of treated seeds
- improved adherence of the product on seeds
- easier cleaning of the treating device.

Thus Formula M technology integrates the advantages of older solvent-based formulations with those of water-based products.

Results

Treated seed was tested immediately after application to identify the impact of different formulation variants on flowability during the selection process, measuring seed flow for 2 s in 20-s intervals in a special funnel (Flow Test) under laboratory conditions. The non-Formula M formulations show a constant increase of flowability over the full length of the test, whereas Formula M products reach their final speed of flow already in the middle of the test period at a 5–10% higher rate.

During practical application tests in commercial seed plants in Germany, CELEST® Formula M showed, in comparison with competitor seed treatments, an increase of seed treatment efficiency between 10 and 35%, with an average of about 15%. In a seed-treatment facility with 12 t/h capacity, this could mean additional 30 bags per hour or 1.5 palettes per hour. As treated seed flows better immediately after the treatment process, there is also a lower increase of the volume of treated seed in the seed bag.

Another important benefit of the Formula M technology is a significant reduction of dust-off and better stickiness on the seed. Under the defined testing parameters, fine dust levels in wheat of Formula M-treated seeds are in the range of 0.5 g dust to 2 g/100 kg seed. This is a significant improvement over non-Formula M internal or competitor products, which result in dust-off values between 2 and 5 g. The reduced dust-off means more product remains on the seed, but more importantly, there is a lower risk of exposure for workers during the seed-treatment process and bagging, and it is also safer for users in the field when emptying bags into the driller. A characteristic of the Formula M technology is that it does not increase stickiness to the seed treatment equipment or affect its cleaning as it adheres better on the seed, and not to the machines.

The new Formula M technology provides, in addition, a significant improvement in application quality. It results in a more uniform and equal seed-to-seed distribution of the product on the individual grain, and reduces the risk of single seeds being treated with too high or too low an amount of the product. A more intense colouring of the treated seeds results in a better visual appearance of seeds, which is an important parameter of treatment quality.

Summary and conclusion

The development of the Formula M technology by Syngenta focused on seed-treatment products used in cereals, because in this crop seed treatments are, in general, applied as slurry diluted in water with no additional binders or colorants, etc. Formula M-based products are already available for the main Syngenta cereal seed treatments based on difenoconazole, fludioxonil and a range of mixture products across Europe. Additional combinations are in development or in the registration process.

The initial target of the Formula M technology was to overcome the weaknesses of FS seed-treatment formulations in comparison with LS products, in particular to improve the initial flow of treated seeds after treatment and allow easy cleaning of the treatment equipment. Both benefits are combined in this new formulation technology, seen in commercial application, as a significant improvement in treatment capacity was demonstrated in a number of large-scale tests in German seed-treatment facilities. The strong reduction in dust-off is another important aspect of this new technology. Proper cleaning of seeds before treatment or careful handling of treated seed during transport and storage would also influence dust-off in addition to the seed-treatment formulation. Formula M-based products provide a clear advantage over conventional formulation technologies: in particular, the more uniform seed-to-seed distribution and better colouring of treated seed underline the high quality of the treatment and ensure customers have confidence in the quality of seed supplied.

ThermoSeed treatment – a novel disinfection technology for vegetable seeds

G Forsberg[1] and V Sanchez-Sava[2]

[1]SeedGard AB, Svalövsvägen 3, 756 51 Uppsala, Sweden; [2]Incotec Holding, International Technology Research, Westeinde 107, 1601 BL Enkhuizen, the Netherlands

Email: gustaf.forsberg@seedgard.se

Summary

ThermoSeed, a method for thermal disinfection of seeds, has been developed in Sweden over approximately 12 years. The method (Forsberg, 2001) is based on the use of precisely controlled hot, humid air, in ways adapted for optimum effect in every individual seed lot. It has been used in cereals on a commercial basis since 2002 as an alternative to chemical seed treatment. In official evaluations, ThermoSeed-treated barley seed has generally given higher yields than seeds treated with conventionally used chemicals.

Recently, research has shown that the method also has potential for use in various kinds of vegetable seeds. In tests with carrot seeds severely infected with *Alternaria* sp., as well as spinach seed infected with a number of different pathogens, ThermoSeed treatment has shown promising effects. Therefore the method gives a perspective for more sustainable large-scale disinfection of vegetable seeds in the future.

Introduction

Seed disinfection is important for maximum crop yield and quality. Chemical seed treatment is widely used, but fear for residues in food and the environment has lead to a search for alternatives. Thermal seed disinfection in the form of hot water treatment is used, mainly for organic vegetable seed, but with some limitations, particularly regarding capacity.

As a result, a patented method for thermal seed disinfection using minutely controlled hot humid air was developed in Sweden. The method gives a large-scale heat exposure that is seed-to-seed uniform and precise – a necessity for optimum disinfection avoiding negative influence on seed vigour. The method has been used for industrial cereal seed treatment in Sweden since 2002. Official field evaluations in Sweden have concluded that ThermoSeed treatment has given average yield levels at least equivalent to conventional chemical seed treatment, and ≈3% higher yields than chemical treatment in barley (Johnsson, 2003, 2004; Wiik, 2008). Shelf-life studies indicate that ThermoSeed does not create any higher vulnerability compared with commonly chemically treated seeds.

Due to increasing customer demand for 'clean starting material' in the vegetable market, tests have been conducted to investigate potential contributions of the new method in this area, both together with seed companies and within the frames of the EU-project STOVE (QLK5-2002-02239, www.stove-project.net). Since the method is particularly well suited for large-scale application, carrot and spinach seed have been chosen as the model crops for this work.