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Prevention and control of mite infestation in rapeseed

by

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ABSTRACT

At the end of July and beginning of August 2003, six loads of rapeseed, varying in mc between 7.3 and 8.3% moisture content (mc) were received. These comprised three of Recital, two of Pollen and one of Royal. Since the intention in this first year was to assess the risks of current practice - storage at 9% mc (and ventilation using equipment designed for cereals aeration), attempts were made to dampen the grain and this resulted in mcs between 8.9 and 9.8% beneath the surface. This coincided with equilibrium relative humidities(erh) of 73-77% at 25°C as determined by dew-point meter.

The two driest bins were left untreated as controls; the two dampest were top-dressed with diatomaceous earth at 3g/kg, and the others were treated at 1g/kg. After 12 weeks, the moisture content at the surface of all bins had reached nearly 12% and there were several thousand mites per kg, despite the DE treatments. Beneath the surface, numbers varied between a few hundred per kg in the driest grain to over 10,000/kg in the dampest.

Despite ventilation, heating of seed to over 35°C occurred in one bin at 9.1-9.2% mc and this had to be remedied by higher-rate ventilation. To achieve the first cooling front, reducing temperatures from 20-25°C to 15°C took 420h, nearly 3x the expected fan hours to achieve the same cooling with cereals, but problems with the automatic cooling regime delayed the second cooling front.

At the beginning of August 2004, three ca 25t loads of rapeseed, varying in mc between 7.1 and 7.3% were received. Each was divided between two bins. The aim was to assess the risks associated with current best practice, ie storing at 7.5% mc and at half depth to account for the higher resistance of rapeseed in comparison with wheat and the consequent effects on cooling speed.

The two driest bins were left untreated as controls, the two dampest were top-dressed with DE at 3g/kg, and the others were treated at 1g/kg. Mites reached levels of several thousand per kg at the surface of control bins where the mc exceeded 11% but numbers were below 100/kg below the surface and where top dressing of DE had been applied. Mean temperatures at 1m fell below 15°C by early October after 200h aeration to below 10°C. However, despite the greater aeration rate, temperatures fell little more rapidly than in the first year; the only difference was in the fewer hours of aeration required.

SUMMARY

Introduction

A greater knowledge of oilseed storage principles would help store managers minimise infestation, fungal disease, mycotoxin, and oil deterioration risks. **S**tored rapeseed is at increased risk from mite infestation following the withdrawal of organophosphate (OP) pesticide treatments. Even assuming the best storage conditions, the surface of a rapeseed bulk will absorb atmospheric moisture during the winter, allowing mite infestations to proliferate.

Small changes in the moisture content of oilseed rape are much more significant than for cereals due to the different equilibrium relative humidity / moisture content relationship. The main market requirement for rapeseed is an oil content above 40% and free fatty acid content below 2% and storage needs to maintain these qualities.

In 1995, two-thirds of farmers stored rapeseed as though it were a cereal, i.e. floor dried and cooled at rates one-third of those required. Mites were present at 90% of sites where seed was at risk of infestation. The main requirement for oilseeds is therefore the availability of an effective protectant, preferably applied as a surface treatment and combined with cooling. No OPs are approved for application to oilseeds. However, diatomaceous earths which act by physical action and are thus considered outside the scope of COPR, have been marketed in the UK since October 2001 and have recently been approved by the oilseed crushers.

This study assessed the effectiveness of top-dressing combined with cooling, both at recommended rates and at one-third to one half airflow rates usually used with rapeseed. Reduced airflow rate may be justified because of the reduced threat from insects to rapeseed. However, a serious surface infestation of saw-toothed grain beetle, *Oryzaephilus surinamensis* L., in rapeseed has been reported.

Methods

The experiments were based on storage of oilseed rape in six cooled 20t, 3m deep bins over 2 seasons. Each year, mite numbers were assessed monthly by sampling. Temperatures and moisture contents of seed were monitored to explain changes in pest numbers. FFA levels in seed were also compared each year.

In the first year, seed was stored at the maximum market moisture content of ca. 9%. Two bins of seed were cooled, as is common practice, at approximately one-half the recommended airflow. Two were top-dressed with 1g/kg DE and two were treated with 3g/kg DE. Two pest species of mites were added in known number to ensure equal pest challenge and surface samples of seed were taken and exposed to saw-toothed grain beetle to determine the insect threat. The equilibrium at two temperatures between moisture content

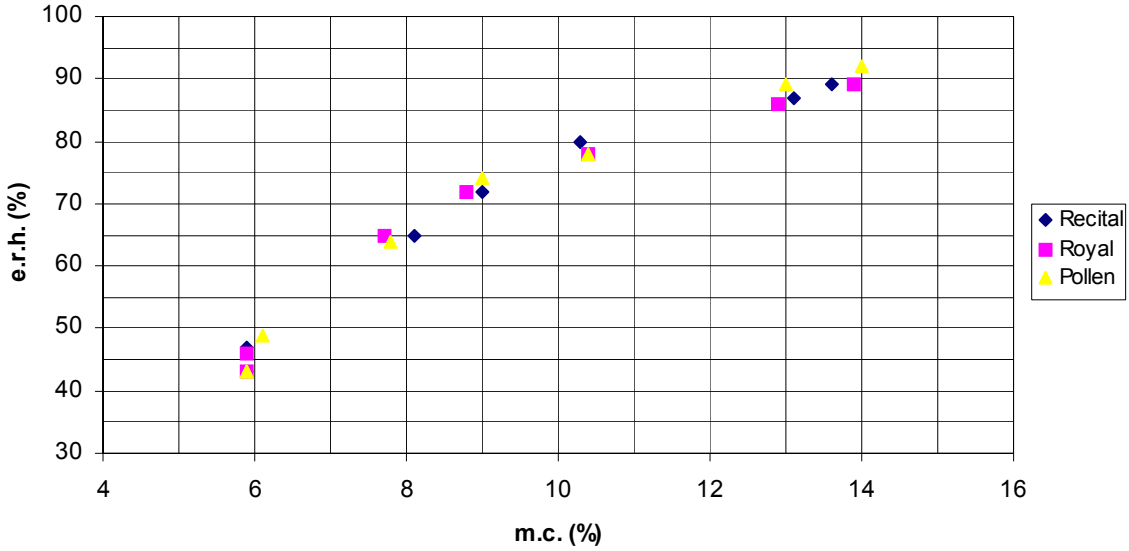
and relative humidity of the three rapeseed varieties used in the farm-scale trials were determined by dew point determination.

In the second year, the seed was stored at ca. 7.5% and aeration was increased by storing at half the depth used with cereals, as is recommended. The DE treatments were again applied to four of the six bins, as in the first year.

Results

The safe relative humidity for storage, below which fungi and mites cannot increase, was 7.6-8.0% mc (Fig. 1), the highest value being for the variety Recital and the lowest for Royal. Another critical point for mc is 80%: above this level *Penicillium verrucosum* can grow; at over 85% it can produce Ochratoxin A (OTA). The corresponding mcs were about 10 and 12% respectively.

Fig. 1. The moisture content equilibrium relative humidity relationship for 3 rapeseed varieties at 25°C (absorption).



In 2003-4, the seed was dampened to 8.9-9.3% mc (72-74% erh) in four of the six bins as measured by the moisture contents at 1m and 2m. The remaining two bins were those treated with DEs, one at 1g/kg (Bin 5) which was 9.3-9.6% mc (74-76% erh) and one at 3g/kg (Bin 2) which was 9.5-10.0 % mc (77-79% erh). Moisture contents beneath the surface rarely varied by more than 1% between samplings (Fig. 2). In contrast, the moisture contents of seed at the surface rose to a peak of above 13% (86-88% erh) in January (Fig. 3).

Fig. 2. 2003-4 Moistures at 1m in six bins of rapeseed at about 9% mc.

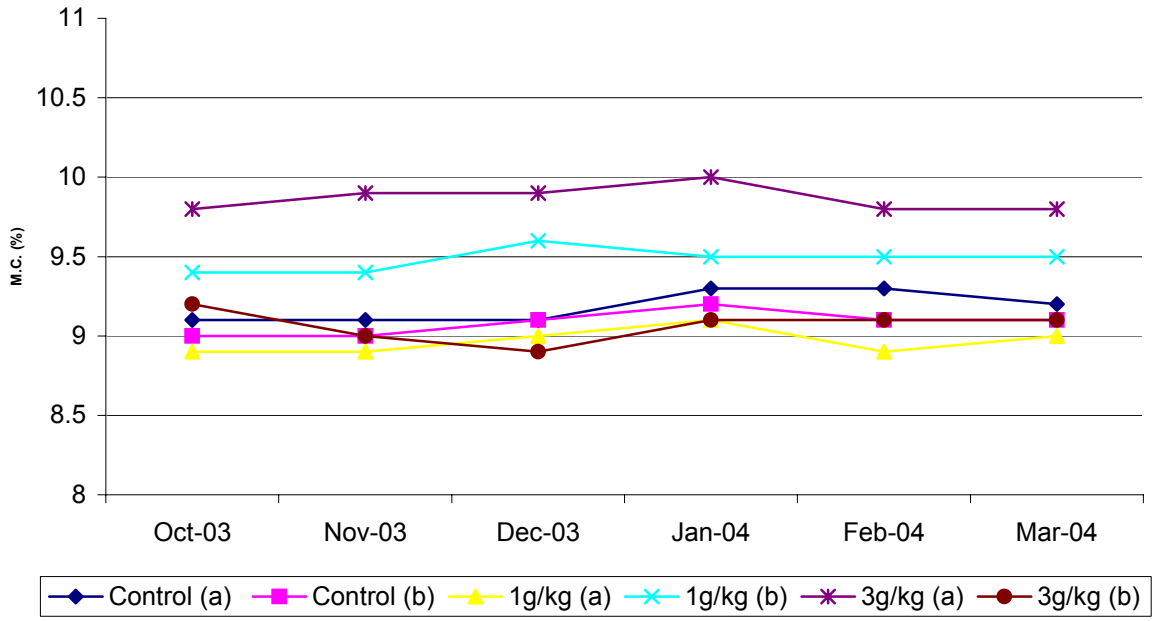
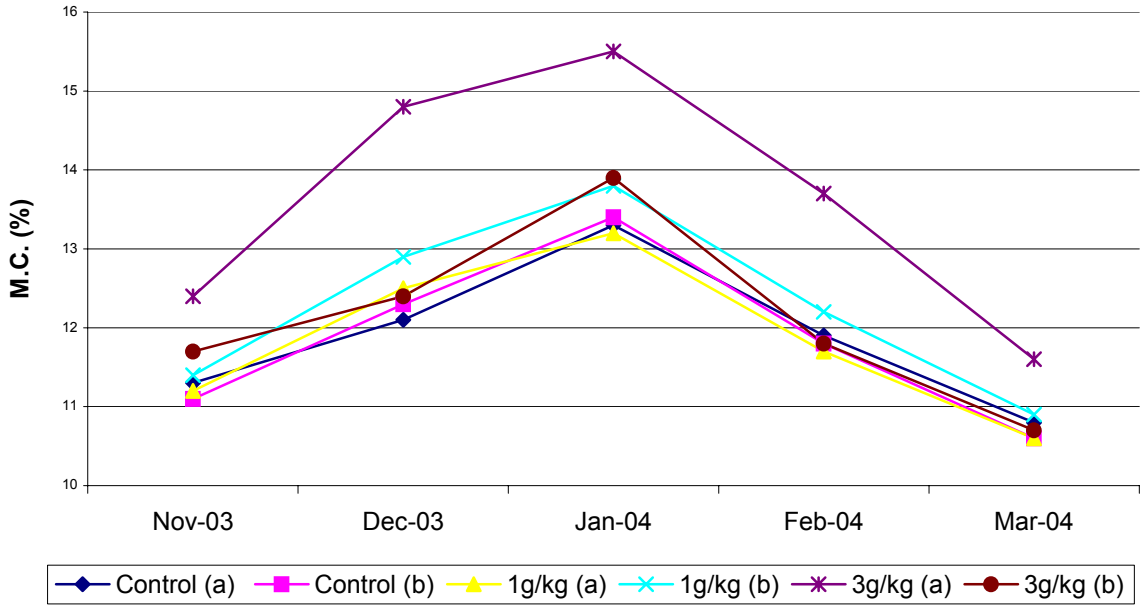


Fig 3. 2003-4 Moistures at the surface in six bins of rapeseed at about 9% mc.



In 2003-4, the most numerous mites in seed at about 9% mc were *Acarus* sp. At 1m, *Acarus* numbers rose steadily and usually exceeded 1,000/kg by March. The exception was Bin 2 where mites exceeded 10,000/kg by December (Fig. 4).

At the surface though, mites exceeded 10,000/kg in five of the six bins by December or January (Fig. 5). The exception was Bin 6, treated with 3 g/kg DE. This bin heated during storage and contained less than 1,000 mites/kg, even in March. Since there was little difference between bins, it can be concluded that the surface DE treatments did not control *Acarus* populations when the bulk mc was 9% or above.

Fig 4. 2003-4 *Acarus* numbers at 1m in six bins of rapeseed at about 9% mc

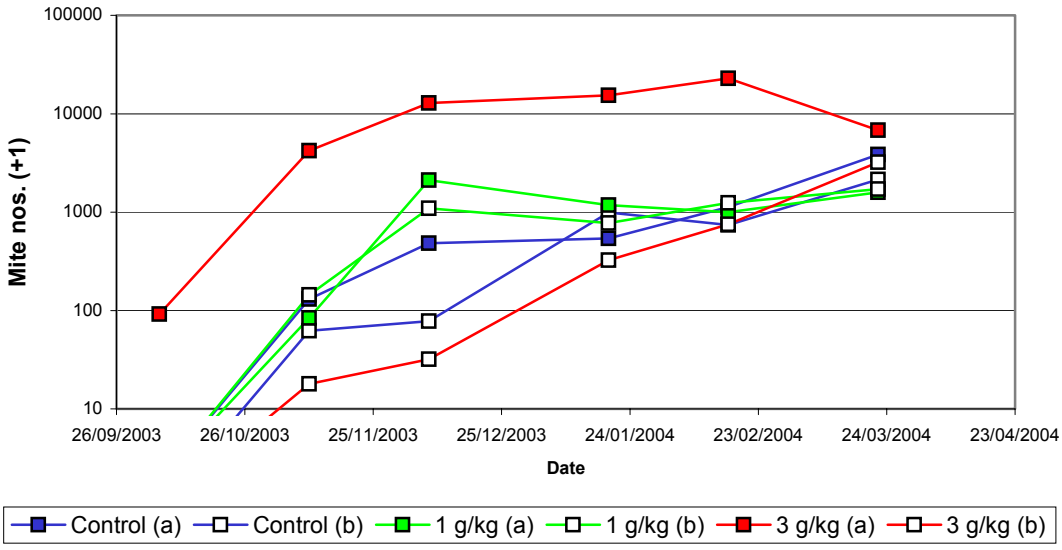
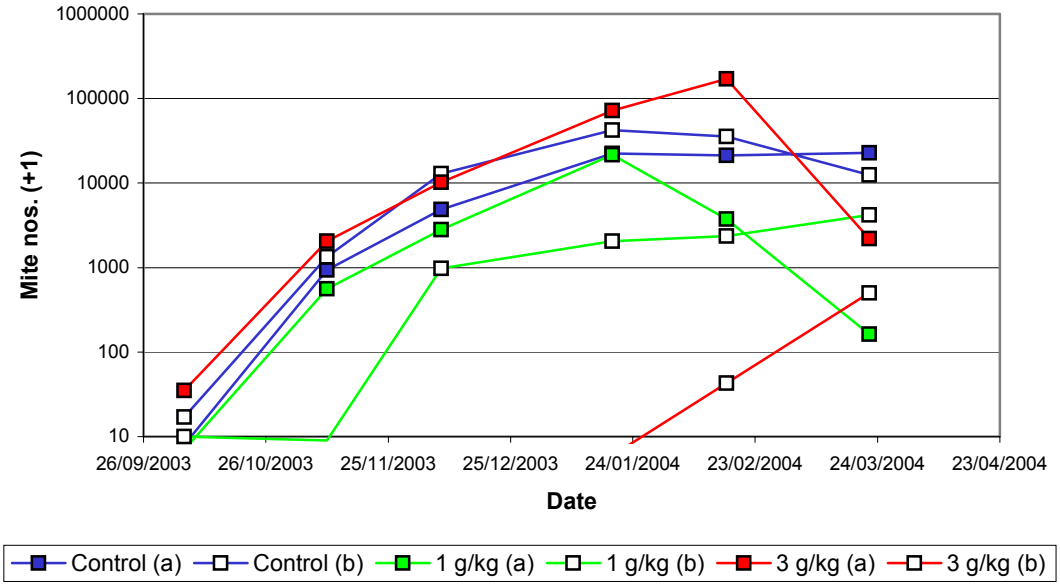


Fig 5. 2003-4 *Acarus* numbers at the surface of six bins of rapeseed at about 9% mc.



In 2004-5, the seed was delivered at 7.1-7.3% moisture content (58-60% erh) and fell by 0.2-0.4% mc at 1m and 2m during the early stages of cooling (Fig.6). Surface moisture contents rose to a peak of about 11% (80% erh) at the end of November (Fig. 7).

Fig. 6. 2004-5 Moistures at 1m in six bins of rapeseed at about 9% mc.

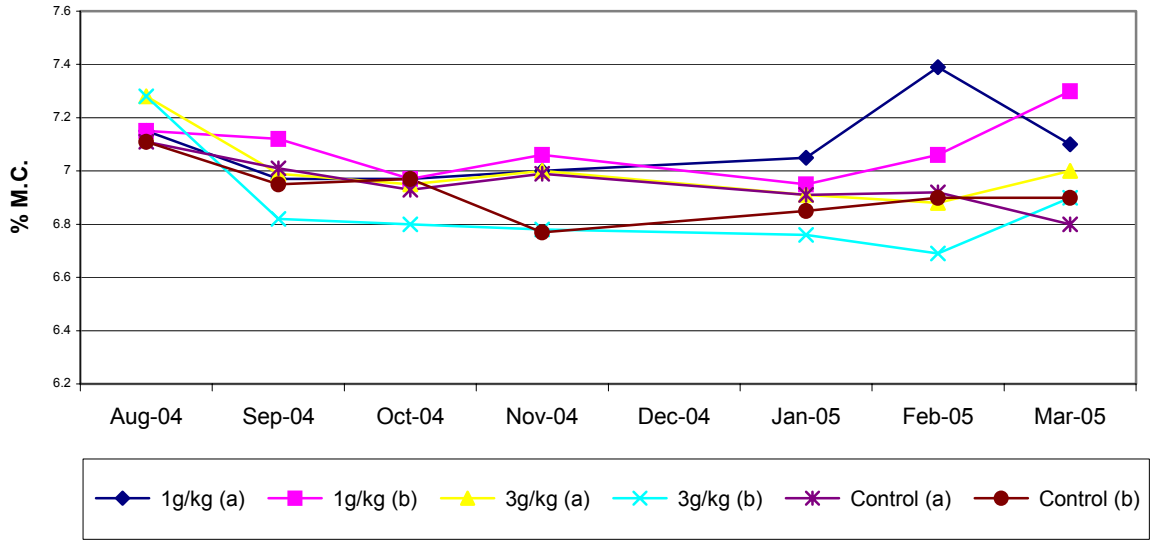
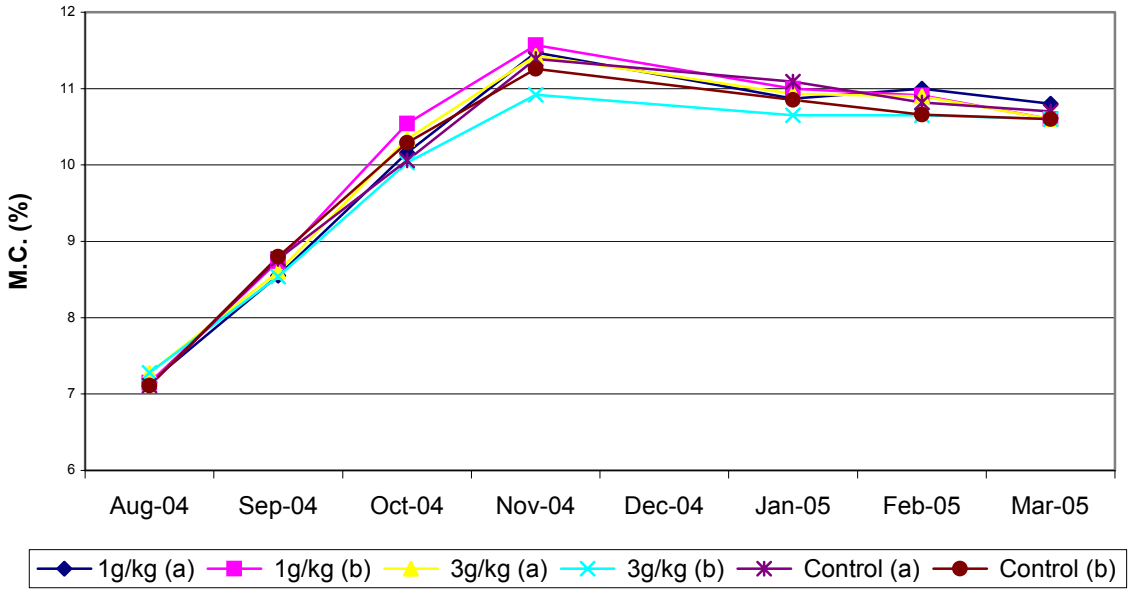


Fig. 7. 2004-5 Moistures at the surface of six bins of rapeseed at about 9% mc.



In 2004-5, *Acarus* were again the most numerous mite species and exceeded 10,000/kg at the surface of the control bins (Fig. 8) but were usually below 1,000/kg at 0.75 and 1.5 m depth (Fig. 9). There were few *Acarus* in any of the top-dressed bins. It can therefore be concluded that this big difference in surface numbers of mites between top-dressed and untreated bins indicates the success of DE treatments in seed at about 7% mc.

Fig 8. 2004-5 *Acarus* numbers at the surface of six bins of rapeseed at about 9% mc.

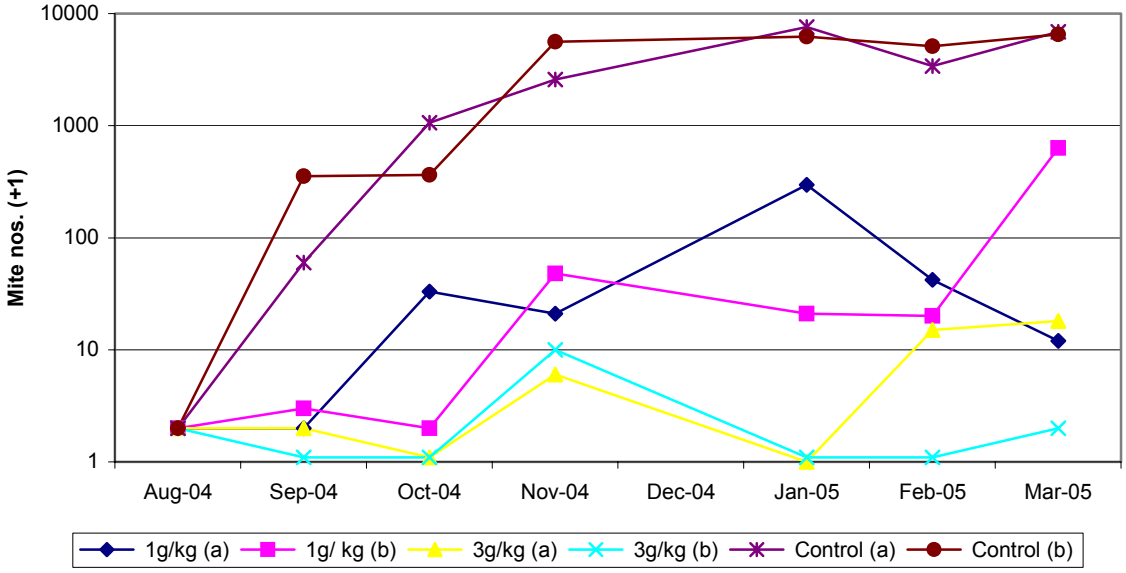
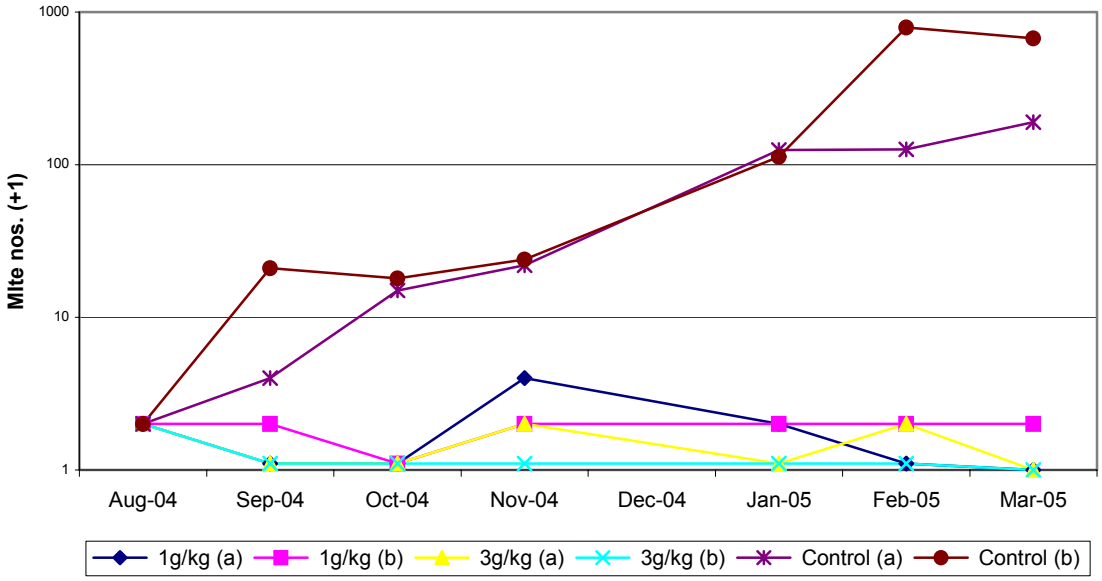


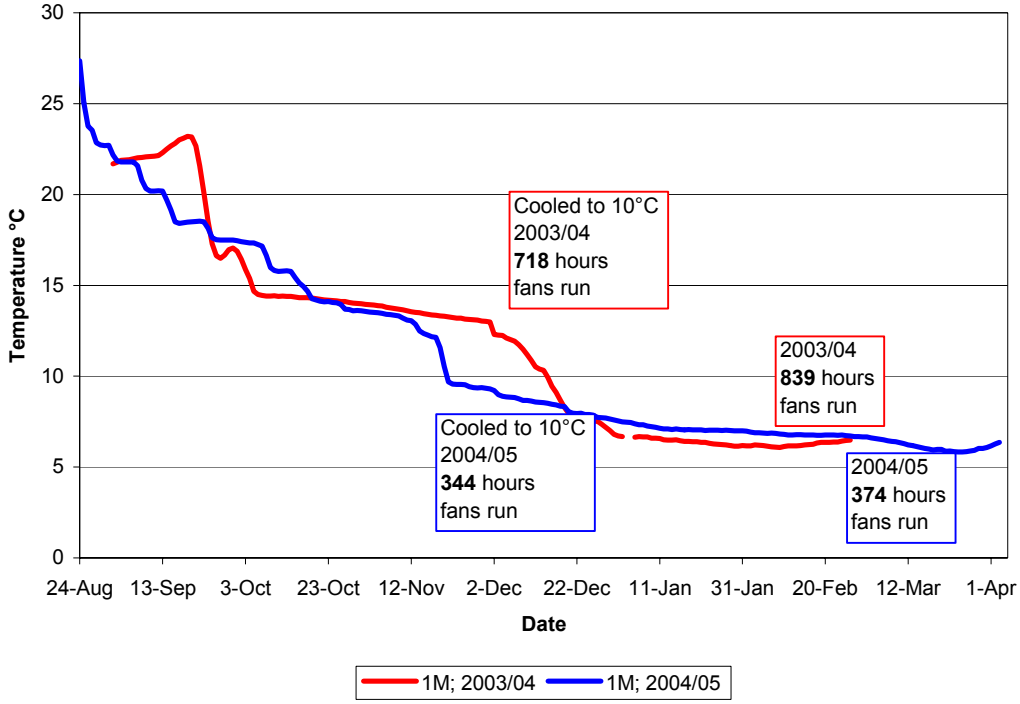
Fig 9. 2004-5 *Acarus* numbers. at 1m in six bins of rapeseed at about 9% mc.



In 2003-4, in seed at 9% mc, free fatty acid levels were initially 0.2-0.4% and at the end of the test were in the range 0.7-3.1% at the surface, 0.3-1.9% at 1m and 0.5-1.5% at 2m. The greatest changes therefore appeared to be at the surface where mcs and mite numbers were highest and the greatest changes occurred in Bins 2 and 6, which were initially the dampest. In 2004-5, in seed at 7%, ffa levels did not show any consistent changes during storage.

The rates of cooling in 2003-4, when airflows were half the recommended rate because the seed was stored at the same depth as cereals, and in 2004-5, when the seed depth was halved, were similar (Fig. 10). However, the hours of aeration in 2003-4 were approximately double those in 2004-5.

Fig. 10 Rates of cooling in 2003-4 (9%mc) and 2004-5 (7%mc)



Less than 1% of saw-toothed grain beetle died after 21 days on untreated rapeseed samples and less than 20% died on surface treated samples at 1 and 3g/kg taken from the 2003-4 test. However, after 7 weeks, the beetles in untreated samples had increased 1.3-3.1 fold while populations on treated seed were inhibited by 68-97%.

Discussion

Earlier work indicated slightly greater variation than described here, between winter and spring sown varieties, Hektor and Gulle and a Canadian 'zero-zero' variety, Tower. These varieties were in equilibrium with 7.5, 7.7 and 8.3% mc respectively at 70% erh (adsorption curve) which used to be considered the safe storage erh. This was a range of about 0.8% mc at 70% rh, compared with 0.5% at 65% rh noted in these experiments. The older varieties, Hektor and Gulle may therefore have had significantly lower safe storage mcs than the zero-zero varieties.

There was little difference between the rate of cooling when the grain was stored at the same depth as cereals (effectively halving the airflow), with storing the seed at half depth, to ensure the airflow was as recommended. There was a difference however in the hours the fans operated which was, as expected, approximately double. This may suggest that the depth of stored seed for cooling need not be reduced to ensure the higher airflow rate necessary for inhibiting insect development for cereals (because few insects develop in oilseed rape). Nevertheless, this reduced airflow was not sufficient to prevent heating in one of the bins of seed stored at the higher mc. The heating observed was unlikely to have been solely due to fungal

activity because the predominant species is not associated with grain heating and the numbers detected of the other species were even below the threshold for visible mould so hydrolysis or oxidation of the oil may have contributed.

This project has shown heavy infestations will occur throughout the bulk if seed is stored at the market standard of 9% and that even at 7% mc, surface infestations are inevitable. While a prophylactic surface admixture of a DE at the higher mc will have little effect on the mite populations at 9% mc, it will largely eliminate infestations at lower mcs and may therefore give farmers peace of mind when combined with proper drying and cooling strategies.

In studies between 1975 and 1978, mean mite numbers in seed at 8% mc peaked at ca 3,500/kg in unaerated bins compared with 500/kg in cooled bins while at 9% mc, the corresponding figures were 36,000/kg and 55,000 in aerated bins vs 1700/kg and 500/kg in uncooled bins. The results indicate that without cooling, mite populations would have been about 7 times higher at 8% mc and 20-100 times higher at 9% mc than those observed in the current project. The current trials have confirmed that the problem of surface infestations will exist even at 7% mc. The parallel survey to this project of 100 rapeseed farms in 2004-5, (Armitage et al., 2005) indicates a correlation between mite numbers and mcs beneath the surface which indicates that 8% mc correlates broadly with expected infestations of less than 100/kg.

Changes in free fatty acid are one of the most useful quality indicators for stored rapeseed which cause deterioration of the extracted oil in storage as well as off-flavours. FOSFA contracts indicate a maximum permitted level of 2%. The changes are thought to be caused by oxidation as well as hydrolysis. Changes are most rapid in cracked seed and their fragments even at low mcs of ca. 7% but changes are more rapid at higher moisture contents. The observations in this project have shown that measurable changes to values outside the level of market acceptability DO occur in seed stored at higher moistures, particularly at the surface of bulks. These can be avoided by lower mc levels of bulk storage and by minimising breakage during handling the seed. It is unfortunate that lowering the mc also increases the brittleness of seed, a process that increases noticeably at mcs below 6% mc. With a recommended safe mc of 7.5%, variations between varieties of 0.5% and bearing in mind moisture meter accuracy (+/-0.5% at best for cereals, probably less accurate for oilseeds), there is little margin for error!

While internally developing insects such as grain weevils cannot develop in rapeseed, *Tribolium castaneum* (Herbst) and *Oryzaephilus mercator (Fauvel)* and *O. surinamensis* can increase. The saw-toothed grain beetle used in this study originated from and was cultured on stored rapeseed while the parallel survey to this found a heavy infestation of *Cryptolestes ferrugineu*s (Stephens). The ability of insects to ‘take hold’ on rapeseed is rather unpredictable, and may be related to variety or to the proportion of seed breakage. This is important in the context of cooling rates which in cereals are fast enough to prevent insects completing their life cycle. In rapeseed it is evident that their speed of reproduction is much less and so maintaining the same

rate of cooling may not be as important. In any case, our experiments indicate that cooling will take no longer with a reduced airflow, just longer fan operating times. However, an important rider to this argument is the, as yet unresolved issue of seed heating which is not directly attributable to fungal growth.

Conclusions

- Critical mcs are 7.6-8.0% (depending on variety) to prevent mite and fungal growth and about 10% and 12% mc to prevent OTA forming organisms and appearance of OTA itself.
- Storage of rapeseed, even if aerated, at or above the market mc of 9% will result in mite infestations throughout the bulk.
- Surface application of diatomaceous earths (DE) will NOT be effective where the bulk is at about 9% moisture content (mc).
- Lowered rates of aeration due to increased resistance to airflow of rapeseed may not be sufficient to prevent seed heating but may result in the same speed of cooling with longer fan operating times.
- FFA changes associated with mc uptake at the surface and high mite populations in seed at around 9% may be enough to increase levels above the market threshold of 2%.
- Storage at 7-7.5% mc will ensure few mites below the surface but infestations may occur at the surface as the mc rises to about 11%.
- Surface application of DE under these circumstances seems quite effective.
- DE application to the surface of rapeseed bulks has the potential to inhibit population growth but is unlikely to succeed in eliminating an existing infestation in the short term.
- The need to treat surface mite infestations needs to be reviewed with processors in the light of any commercial thresholds.
- Best practice for rapeseed storage would be aerated storage at below 7.5 % mc with top-dressing using DEs to discourage mite and insect infestation.

TECHNICAL REPORT

INTRODUCTION

There is currently insufficient knowledge of oilseed storage principles which would help minimise infestation, mycotoxin, and oil deterioration risks. In particular**,** stored rapeseed is at increased risk from mite infestation following the withdrawal of organophosphate (OP) pesticide treatments. Even in the best scenarios, the surface of rapeseed will absorb atmospheric moisture during the winter, allowing mite infestations to proliferate. Small changes in mc of oilseeds are much more significant than for cereals due to the different equilibrium relative humidity / moisture content relationship.

The main market requirement for rapeseed is oil content above 40% and free fatty acid content below 2%. During storage, oil content can decline and free fatty acid (ffa) can increase depending on temperature, moisture content, infestation and seed breakage (Appelqvist and Loof (1972). It follows that the marketability of the oilseed depends on how the grain is dried and stored (Armitage, 1980). Mite infestations may also be expected to affect the oil and ffa profiles of the seed, particularly as mites can completely hollow out the seeds. Maintaining quality in store is thus a major challenge.

In 1995 a CSL survey (Prickett, 1997) of nearly 100 sites, storing about 80,000 t of rapeseed, showed at least two-thirds treated rapeseed as though it were a cereal; that is, floor drying and cooling at rates that were one-third those required, and half-dosing with pesticides using the most expensive option at nearly £1/tonne. Few stores monitored for mites and around one in eight stores reported mite problems**,** although the survey also indicated that nearly 90% of the sites had mites present - and were thus at risk of infestation. In addition, over 90% of the separate populations collected from the stores survived the (then) maximum recommended organophosphate pesticide treatment of 8ppm.

The main requirement for oilseeds is therefore the availability of an effective protectant to be applied, preferably as a surface treatment and combined with cooling. No OPs are approved for application to oilseeds, however, diatomaceous earths which act by physical action and are thus considered outside the scope of COPR, have been marketed in the UK since October 2001 and have recently been approved by the oilseed crushers. Laboratory tests funded by HGCA (Collins et al., 2001) have shown DEs to have some efficacy on rapeseed but no practical-scale applications have been attempted.

In 1992 HGCA reviewed research requirements for storage of oilseed (Nellist et al. 1992) and the review's recommendations included the need for studies on storage and optimum cooling strategies. This study attempts to address these issues by studying the effectiveness of top-dressing combined with cooling, both at recommended rates and at the one-third airflow that is usually applied to rapeseed. It may be that this reduced airflow **is** justified because of the reduced threat from insects to rapeseed. At the same time, a

serious surface infestation of saw-toothed grain beetle, *Oryzaephilus surinamensis* L., in rapeseed was reported just before this project started.

The aim of the project was to devise and demonstrate a safe, cost-effective storage strategy for oilseeds based on current knowledge and best practice by:-

1. **a**pplying an integrated pest management regime to oilseed storage based on cooling and surface dressing with DEs.
2. acquiring background information on the equilibrium between moisture content and relative humidity of modern rapeseed varieties.

METHODS AND MATERIALS

Experimental outline

The experiments were based on storage of oilseed in six cooled 20 t, 3m deep bins over 2 seasons. Each year, mite numbers were assessed monthly by sampling and temperatures and moisture content of the seed were monitored to explain changes in pest numbers. FFA levels were also compared each year.

In the first year, the comparison was of seed stored at the maximum market moisture content of ca. 9%. Two bins of seed were treated, as the CSL survey indicated is common practice, at approximately one-third the recommended airflow, two were in addition top dressed with 1g/kg DE and two were treated with 3g/kg DE. Two pest species of mites were added in known number to ensure equal pest challenge and surface samples of seed were taken and exposed to saw-toothed grain beetle to determine the insect threat.. The equilibrium at two temperatures between moisture content and relative humidity of the three rapeseed varieties used in the farm-scale trials were determined by dew point determination.

In the second year, the seed was stored at ca. 7.5% and aeration increased by storing at half depth, as is recommended. The DE treatments were again applied to four of the six bins, as in the first year.

Trial details

Grain - At the end of July and beginning of August 2003, six loads of rapeseed, varying in mc between 7.3 and 8.3% mc as measured by moisture meter, were received. These comprised three of Recital, two of Pollen and one of Royal. Since the received moisture content was some way beneath the required maximum market level of 9%, the grain was dampened during conveying between two bins before being conveyed back into the original bins after standing for 1-6 days to absorb the applied water.

In the second year, three 25t loads of one variety, Royal, at about 7.5% mc as measured on intake by moisture meter, were received from a single source. Each load was divided between two bins so the seed was stored at half the depth of the previous year.

Treatment – Each year, four of the 6 bins were treated, two at 3 g/kg and two at 1 g/kg. Doses were calculated based on 400g/ m^2 = 2g/kg. Sufficient inert dust was weighed into plastic bags and sprinkled onto the surface of the treated replicates. This was then raked in to a depth of 0.3 m.

Aeration - The grain was cooled using 30 W axial fans, switched on and off by differential thermostats set at 6°C. In 2004-5, the differential was reduced to 4°C due to speed the cooling process. Cooling commenced immediately after DE treatment and the airflows were measured with a hot-wire anemometer..

Introduced infestation - Each year, initial populations of approximately 1/kg of *Acarus. siro* L. *and Lepidoglyphus destructor* (Schrank) were achieved by introduction into each bin at three depths and nine columns via a narrow-bore plastic pipe, emptied of grain by vacuum.

Spear samples - Each month, five samples were withdrawn from each bin at the surface, 1m and 2m. Mite numbers were estimated by sieving through 30 mesh per inch and examining the dust under a binocular microscope. Where mite numbers were very high, a disc divided into areas was used (Solomon, 1962). The moisture content of the samples was determined by the ISO oven method, drying in a ventilated oven at 130°C for 2 h.

Temperatures - Temperatures were measured in each bin by a central row of thermocouples. Data was retrieved monthly, inserted into spread sheets and analysed to coincide with the sampling occasions.

Fungi - In 2003-4 sub-samples of seed at about 9% mc from the first and final samplings were examined for fungi by a dilution technique. The dilution medium was 0.1% peptone (Oxoid) water and samples were soaked for 1/2 hour and then processed in a stomacher device for 1 minute. The agar medium used was DG18 (Oxoid) with Chloramphenicol and the incubation temperature was 25°C, spread plate technique was used and plates were incubated for 5 days. Fungi were not looked for in 2003-4 because the seed, at 7% mc (below 65% erh) was below the critical limit for fungal growth.

Free fatty acid analysis - Initial and final samples were taken for ffa analysis by bulking samples from each depth in each bin. The oil was extracted using petroleum ether (boiling range 40-60C), this was evaporated under vacuum at <40C and final traces of solvent were removed using a stream of nitrogen gas. Aliquots of the extracted oil were analysed for free fatty acids using CCFRA (UKAS accredited) method based on British Standard BS EN ISO 660:2000 with titration of the free acids using standard sodium hydroxide solution after dissolution of the oil in hot neutral ethanol. Results are expressed as percentage by weight of oleic acid in the extracted oil.

Equilibrium between relative humidity and moisture content of three rapeseed varieties - In 2003-4, samples of the three varieties taken at delivery were used for the determination of erh/mc equilibrium. The moisture content was determined gravimetrically by drying duplicate samples of 4 to 6g were weighed and the dried in an oven at 103°C for 5 hours according to BS 4289. Samples of each variety were dried by spreading on a tray in a thin layer and leaving for a week or so in a fume cupboard. A range of moisture contents were obtained by increasing the moisture content of the samples following the relevant CSL SOP EFF 230. Appropriate quantities of de-ionised water were added to samples and each sample was shaken for 1 min after the addition of the water and then placed in a CE room at 10°C. They were shaken again for 15 sec after time intervals of 1 hour, 2 hours, 3 hours, at the end of the first day and then daily for 3 days. The samples were not used for at least a week after the addition of the water.

The relative humidity of the conditioned samples was determined in duplicate using about 200 g seed in 0.45 kg Kilner jars using a dew point meter, allowing 1h for each sample to equilibrate with the dew point probe and ½ h between readings. The calibration of the dew point meter was checked using saturated salt solutions of MgCl2, Mg(NO3)2, NaCl and KCl subtending relative humidities of 32.8, 52.9, 75.3 and 84.3 respectively. These measurements were carried out at 10°C and 20°C.

Effects on saw-toothed grain beetle of top-dressing rapeseed with DE- Surface samples of oilseed rape taken from the six bins in October 2003 were bulked and stored in a room maintained at 10^{o}C before use. A proportion (10%) was broken up in a grinder. The rapeseed from each bin was divided into approximately 40 g lots and five replicate jars were set up for each bin.

A field strain of *O. surinamensis* was used that had been bred on oilseed rape for at least eight generations at 25^{o}C and 70% rh. and 25 adults of unknown age were added to each jar. The jars were put into a controlled environment room at 25^{o}C and 70% rh. for 21 days after which time adult mortality was assessed. The seed was then returned to the jars and incubated for a further 7 weeks to allow next generation of insects to develop when numbers of live and dead F_1 insects were counted to assess inhibition of population development.

RESULTS AND DISCUSSION

Equilibrium relative humidity and moisture contents

The safe relative humidity for storage, because fungi and mites cannot increase below this level, is 65% rh, corresponding to 7.6-8.0% mc (Table 1), the highest value being for Recital and the lowest for Royal. Another critical point for mc is 80% to allow the growth of Ochratoxin (OTA) forming *Penicillium verrucosum* and 85% for the production by this fungus of OTA. The corresponding mcs were about 10 and 12% respectively.

In 2003-4, the seed in the six bins was dampened to 8.9-9.3% mc (72-74% erh) in four of the six bins as measured by the moisture contents at 1m and 2m (Table 2). The remaining two bins were those treated with DEs, one at 1g/kg (Bin5) which was 9.3-9.6% mc (74-76% erh) and one at 3g/kg (Bin 2) which was 9.5-10.0 % mc (77-79% erh). Moistures beneath the surface rarely varied by more than 1% between samplings. In contrast, the moisture of seed at the surface rose to a peak of above 13% (86-88% erh) in January.

In 2004-5, the seed was delivered at 7.1-7.3% moisture content (58-60% erh) and fell by 0.2-0.4% mc at 1m and 2m during the early stages of cooling (Table 3). Surface moistures rose to a peak of about 11% (80% erh) at the end of November.

In 1977, Pixton and Warburton found slightly greater variation than described here, between winter and Spring sown varieties, Hektor and Gulle and a Canadian 'zero-zero' variety, Tower, which were in equilibrium with 7.5, 7.7 and 8.3% mc respectively at 70 % erh (adsorption curve) which was then considered the safe storage erh. This was a range of about 0.8%mc at 70% rh, compared with 0.5% at 65% rh noted in these experiments (estimated by extrapolation to ca 8.2-8.7% mc at 70% rh). The older varieties, Hektor and Gulle may therefore have had significantly lower safe storage mcs than the zero-zero varieties Tower and the three varieties tested in this project.

Temperatures and aeration

In 2003-4, (Fig. 1) the seed was delivered at 20-22°C and drifted up to about 25°C before the fans were switched on 12/9 delivering 4.4-4.7 cum/h/t, approximately half the rate recommended for cereals. In 419 hours aeration up to 6th October, the temperatures Fig 2) were reduced to below 15°C in all bins but one. The exception was Bin 6, one of those surface treated at 3g/kg DE, where the seed heated up to a peak of 35°C, despite the ventilation and had to be cooled for about 280 h continuous ventilation at 5x the experimental rate. Between 6th October and 27th November, the fans did not blow due to a failure of the automatic switching but when this was corrected, temperatures fell to below 10°C after over 700 h aeration by 17th February and finally to about 7°C by 12th March after 850 h aeration.

In 2004-5, (Fig. 3) the seed at 7% mc was delivered at 20-25°C and mean temperatures at 1m fell below 15°C by early October after 200 h aeration (Fig 4) at 8.5- 10.2 cu m/h/t, to below 10°C by mid November after 350h aeration and to about 7°C by the end of the test and using 374 h aeration.

There was little difference between the rate of cooling when the grain was stored, as is common practice at the same depth as cereals, (thus effectively halving the airflow), with storing the seed at half depth, to ensure the airflow was as recommended. There *was* a difference however in the hours the fans operated which was, as expected approximately double. This may suggest that the depth of stored seed for cooling need not be reduced to ensure the higher airflow rate necessary for inhibiting insect development for cereals (because few insects develop in oilseed). Nevertheless, it should be noted that this reduced airflow was not sufficient to prevent heating in one of the bins of seed stored at the higher mc. The heating observed was unlikely to have been solely due to fungal activity (see below) and hydrolysis or oxidation of the oil may have contributed.

Mite numbers

In 2003-4, the most numerous mites in seed at about 9% mc were *Acarus* sp. At 2m, they were usually below 1000/kg (Table 4) with one exception, the damper Bin 2, which was top-dressed with 3g/kg DE. Here populations exceeded 1,000/kg by November and peaked at over 10,000/kg by February. At 1m, *Acarus* numbers rose steadily and usually exceed 1,000/kg by the end of the test. Again, the exception was Bin 2 where mcs exceeded 10,000/kg by December. At the surface though, mites exceeded 10,000/kg in five of the six bins by December or January. The exception was Bin 6, treated with 3 g/kg DE and which was the bin that heated during storage where numbers were below 1,000/kg, even in March. Since there was little difference between bins, it can therefore be concluded that the surface DE treatments did not serve to control *Acarus* populations when the bulk mc was 9% or above. *Lepidoglyphus* populations showed similar trends (Table 5), numbers beneath the surface were generally less than 1,000/kg and were between 1,000 and 10,000/kg at the surface. They were more numerous than *Acarus* however in heating Bin 6.

In 2004-5, *Acarus* were again the most numerous mite species in seed at 7% mc and exceeded 10,000/kg at the surface of the control bins but were usually below 1,000/kg at 0.75 and 1.5m depth (Table 6). There were no *Acarus* in any of the top-dressed bins, usually less than 1/kg *Lepidoglyphus* beneath the surface and usually less than 100/kg/kg in the top-dressed bins compared with several thousand per kg in the control bins (Table 7). It can therefore be concluded that this big difference in surface numbers of mites between top-dressed and untreated bins indicates the success of DE treatments in seed at about 7% mc.

Predatory mites occurred more sporadically during the trials. In 2003-4 on seed at 9% mc, gamasid mites were commonest and they occurred throughout the bins and most frequently in the dampest bins (2 and 6)

which were also the dampest (Table 8). In 2004-5, both Cheyletus and gamasids occurred, mainly at the surface of the control bins (5 and 6) (Table 9).

Mites feed directly on oilseed rape, can completely hollow out individual seeds, impart a taint and cause allergies in those handling infested seed, yet paradoxically have not been associated with a rise in FFA levels (Mills et al, 1978). This project has shown that heavy infestations will occur throughout the bulk if seed is stored at the market standard of 9% and that even at 7% mc, surface infestations will be inevitable. While a prophylactic surface admixture of a DE at the higher mc will have little effect on the mite populations, it will largely eliminate infestations at lower mcs and may therefore give farmers peace of mind when combined with proper drying and cooling strategies.

Between 1975 and 1978 (Armitage, 1980), I compared the storage of Primor variety seed at approximately 8% mc (7.8-8.0%) and at 9% mc (9.3-9.6%) mc stored in aerated and unaerated bins. Mean mite numbers in seed at 8% mc peaked at ca 3,500 / kg in unaerated bins compared with 500/kg in cooled bins while at 9% mc, the corresponding figures were 36,000/kg and 55,000 in aerated bins vs 1700/kg and 500/kg in uncooled bins. In the current test, I did not compare unaerated with aerated bins, since the practice is now well established, but the former results indicate that without cooling, mite populations would have been about 7 times higher at 8% mc and 20-100 times higher at 9% mc. By presenting the results as mean numbers of mites, these earlier results perhaps underestimated the seriousness of surface mite populations, even at the lower mc of 8% and the current trials have confirmed that this problem will exist even at 7% mc. The parallel survey to this project of 100 rapeseed farms in 2004-5 (Armitage et al., 2005) indicates a correlation between mite numbers and mcs beneath the surface which indicates that 8% mc correlates broadly with expected infestations of less than 100/kg.

Free fatty acid levels

In 2003-4 in seed at 9% mc, free fatty acid levels were initially 0.2-0.4% and at the end of the test were in the range 0.7-3.1% at the surface, 0.3-1.9% at 1m and 0.5-1.5% at 2m (Table 10). The greatest changes therefore appeared to be at the surface where mcs and mite numbers were highest and the greatest changes occurred in Bins 2 and 6, which were initially the dampest. In 2004-5, in seed at 7%, ffa levels did not show any consistent changes during storage (Table 11).

Changes in free fatty acid are one of the most useful quality indicators for stored rapeseed which cause deterioration of the extracted oil in storage as well as off-flavours. FOSFA contracts indicate a maximum permitted level of 2%. The changes are thought to be caused by oxidation (Steward and Bewley, 1980) as well as hydrolysis (Reuss and Cassells, 2004). Changes are most rapid in cracked seed and their fragments (Appelqvist and Loof, 1972) even at low mcs of ca. 7% but changes are more rapid at higher moisture contents. The observations in this project have shown that measurable changes to values outside the level of market acceptability DO occur in seed stored at higher moistures, particularly at the surface of bulks. These can be avoided by lower mc levels of bulk storage and by minimising breakage during handling the seed. It is unfortunate that lowering the mc also increases the brittleness of seed, a process that increases noticeably at mcs below 7% (Appleqvist and Loof, 1972). With a recommended safe mc of 7.5%, variations between varieties of 0.5% and bearing in mind moisture meter accuracy of +/- 0.5% at best for cereals and probably worse for oilseeds; there is little margin for error !

Fungi

Storage fungi detected included *Wallemia sebi*, *Eurotium* spp, *Aspergillus* spp. and *Penicillium* spp including *P. verrucosum*, responsible for OTA production. Storage fungi were present only in low numbers at the start of the experiment but had increased to over 1,000 colony forming units (cfu) /g in most cases by the end (Table 12). The highest counts were in the dampest bins (2 and 6) where counts were over 10,000 cfu/g and the most numerous fungus was *W. sebi*. The heating that occurred in Bin 6 cannot therefore be solely attributed to fungal activity because the predominant species is not associated with grain heating and the numbers detected of the other species were even below the threshold for visible mould, which is usually around 10,000 cfu/g.

Effects on saw-toothed grain beetle of top-dressing rapeseed with DE

The highest adult mortality and population inhibition were recorded in samples from Bins 5 and 6 (Table 13). However, Bin 5 had been treated with 1 g/kg, whereas Bin 6 had been treated with 3g/kg. Bins 2 and 4 gave similar results even though different doses had been applied. This suggests that the treatments may have been uneven, leading to a variation in doses between the bins. Nevertheless, with population inhibition of two bins at over 90%, the potential of DE treatments against insects in practical conditions is clear. During the same time, numbers in the untreated controls had nearly doubled indicating the ability of this strain to slowly increase on rapeseed.

While internally developing insects such as grain weevils cannot develop in rapeseed, Sinha (1976) found that *Tribolium castaneum* (Herbst) and *Oryzaephilus mercator* (Fauvel) reproduced well, while Amos (1990) found that only *O. surinamensis* could actually increase. The saw-toothed grain beetle used in this study originated from, and was cultured on, stored rapeseed, while the parallel survey to this study (Armitage et al., 2005) found a heavy infestation of *Cryptolestes ferrugineus* (Stephens), even though the laboratory tests indicated it could not increase on rapeseed (Amos, 1990). It is therefore evident that the ability for insects to 'take hold' on rapeseed is rather unpredictable, perhaps related to variety or to the proportion of seed breakage. This is important in the context of cooling rates which in cereals are fast enough to prevent insects completing their life cycle. In rapeseed it is evident that their speed of reproduction is much less and so maintaining the same rate of cooling may not be so of the important. In any case, our experiments indicate that cooling will take no longer with a reduced airflow, just longer fan operating times. However, an important rider to this argument is the, as yet unresolved, issue of seed heating which is not directly attributable to fungal growth.

CONCLUSIONS

- Storage of rapeseed, even if aerated, at or above the market mc of 9% will result in mite infestations throughout the bulk.
- Surface application of diatomaceous earths (DE) will not be effective where the bulk is at about 9% moisture content (mc).
- Lowered rates of aeration due to increased resistance to airflow of rapeseed may not be sufficient to prevent seed heating but may result in the same speed of cooling with longer fan operating times.
- FFA changes associated with mc uptake at the surface and high mite populations in seed at around 9% may be enough to increase levels above the market threshold of 2%.
- Storage at 7-7.5% mc will ensure few mites below the surface but infestations may occur at the surface as the mc rises to about 11%.
- Surface application of DE under these circumstances seems quite effective.
- DE application to the surface of rapeseed bulks has the potential to inhibit population growth but is unlikely to succeed in eliminating an existing infestation in the short term.
- The necessity of treating surface mite infestations needs to be reviewed with processors in the light of any commercial thresholds.
- Best practice for rapeseed storage would be aerated storage at below 7.5 % mc with top-dressing using DEs to discourage mite and insect infestation.

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Table 1

The relative humidity moisture content equilibrium (absorption curve) of three rapeseed varieties at two temperatures.

Moisture content (%)	Relative humidity (%) 20°C	10°C
a. Recital		
5.9	43	41
6.0	47	45
8.1	65	64
9.0	72	71
10.3	80	79
13.1	87	84
13.6	89	89
b. Royal		
5.9	43	41
6.0	46	43
7.7	65	63
8.8	72	69
10.4	78	76
12.9	86	85
13.9	89	87
c. Pollen		
5.9	43	42
6.1	49	47
7.8	64	64
9.0	74	74
10.4	78	77
13.0	89	89
14.0	92	92

Table 2

2003-04 Moisture contents in six bins of rapeseed at ca. 9% moisture content.

	1 Control	3 Control	4 1g/kg	5 1g/kg	2 3g/kg	6 3g/kg
Surface						
6/10/03	11.7	11.5	12.2	12.0	14.5	20.9
10/11/03	11.3	11.1	11.2	11.4	12.4	11.7
8/12/03	12.1	12.3	12.5	12.9	14.8	12.4
19/1/04	13.3	13.4	13.2	13.8	15.5	13.9
16/2/04	11.9	11.8	11.7	12.2	13.7	11.8
22/3/04	10.8	10.6	10.6	10.9	11.6	10.7
1.0m						
6/10/03	9.1	9.0	8.9	9.4	9.8	9.2
10/11/03	9.1	9.0	8.9	9.4	9.9	9.0
8/12/03	9.1	9.1	9.0	9.6	9.9	8.9
19/1/04	9.3	9.2	9.1	9.5	10.0	9.1
16/2/04	9.3	9.1	8.9	9.5	9.8	9.1
22/3/04	9.2	9.1	9.0	9.5	9.8	9.1
2.0m						
6/10/03	9.1	9.1	8.8	9.3	9.5	9.1
10/11/03	8.9	8.9	8.9	9.4	9.6	8.9
8/12/03	8.9	8.9	8.9	9.4	9.6	9.0
19/1/04	9.1	9.1	9.0	9.4	9.7	9.0
16/2/04	9.1	9.0	9.0	9.4	9.5	9.3
22/3/04	9.1	9.0	8.9	9.4	9.5	9.2

Table 3

2004-05 Moisture contents in six bins of rapeseed at ca. 7% moisture content.

	1 1g/ kg	2 1g / kg	3 3g/kg	4 3g/kg	5 Control	6 Control
Surface						
09/08/04	7.2	7.2	7.3	7.3	7.1	7.1
21/09/04	8.6	8.7	8.6	8.4	8.8	8.8
25/10/04	10.2	10.5	10.3	10.0	10.1	10.3
29/11/04	11.5	11.6	11.4	10.9	11.4	11.3
04/01/05	10.9	11.0	10.9	10.7	11.1	10.9
07/02/05	11	10.9	10.9	10.6	10.8	10.7
29/03/05	10.8	10.6	10.6	10.6	10.7	10.6
0.75m						
09/08/04	7.2	7.2	7.3	7.3	7.1	7.1
21/09/04	7.0	7.1	7.0	6.8	7.0	7.0
25/10/04	7.0	7.0	7.0	6.8	6.9	7.0
29/11/04	7.0	7.1	7	6.8	7.0	6.8
04/01/05	7.1	7.0	6.9	6.8	6.9	6.9
07/02/05	7.4	7.1	6.9	6.7	6.9	6.9
29/03/05	7.1	7.3	7	6.9	6.8	6.9
1.5m						
09/08/04	7.2	7.2	7.28	7.3	7.1	7.1
21/09/04	6.9	6.9	6.89	6.9	6.9	6.9
25/10/04	6.9	6.7	6.8	6.9	6.9	6.8
29/11/04	6.8	6.7	6.75	6.9	6.7	6.9
04/01/05	6.7	6.7	6.72	6.9	6.8	6.8
07/02/05	6.9	6.9	6.66	6.9	6.8	6.8
29/03/05	6.8	6.8	6.7	7.1	6.7	6.8

Table 4

2003-04 Numbers of *Acarus* / kg in six bins of rapeseed at ca.9% moisture content.

	1 Control	3 Control	4 1g/kg	5 1g/kg	2 3g/kg	6 3g/kg
Surface						
6/10/03	7	16	6	9	34	0
10/11/03	933	1345	561	8	2053	2
8/12/03	4847	12958	2820	977	10218	6
19/1/04	22394	42445	21527	2061	72207	5
16/2/04	21232	35585	3744	2368	170192	42
22/3/04	22741	12460	161	4200	2199	499
1.0m						
6/10/03	1	0	1	1	91	0
10/11/03	129	61	83	143	4198	17
8/12/03	483	77	2118	1089	12854	31
19/1/04	540	992	1175	776	15427	324
16/2/04	1128	742	1000	1237	22832	752
22/3/04	3849	2145	1584	1708	6780	3220
2.0m						
6/10/03	0	0	0	1	185	0
10/11/03	45	26	69	20	2549	0
8/12/03	313	279	424	174	9674	55
19/1/04	198	370	923	934	6619	57
16/2/04	1867	292	746	366	13101	131
22/3/04	255	482	364	248	3557	234

Table 5

2003-04 Numbers of *Lepioglyphus* / kg in six bins of rapeseed at ca.9% moisture content.

	1 Control	3 Control	4 1g/kg	5 1g/kg	2 3g/kg	6 3g/kg
Surface						
6/10/03	768	47	19	0	227	20
10/11/03	2412	433	656	2	190	11
8/12/03	1539	299	4971	532	35	1870
19/1/04	3941	741	9471	471	111	4682
16/2/04	5434	146	2671	1064	1026	198
22/3/04	8864	250	524	1218	103	246
1.0m						
6/10/03	21	5	16	2	172	50
10/11/03	400	12	74	65	318	515
8/12/03	162	1107	849	169	695	348
19/1/04	286	24	275	40	173	175
16/2/04	157	16	80	75	230	496
22/3/04	478	16	177	10	2027	171
2.0m						
6/10/03	30	2	10	1	279	166
10/11/03	119	20	56	23	509	277
8/12/03	166	49	507	260	792	726
19/1/04	107	45	376	42	171	340
16/2/04	253	3	249	144	468	166
22/3/04	362	17	85	49	370	308

Table 6

2004-05 Numbers of *Acarus* / kg in six bins of rapeseed at ca.7% moisture content.

	1 1g/ kg	2 1g / kg	3 3g/kg	4 3g/kg	5 Control	6 Control
Surface						
21/09/04	0	0	0	0	7	0
25/10/04	0	0	0	0	32	163
29/11/04	3	0	2	0	1848	456
04/01/05	0	0	0	0	13880	872
07/02/05	0	0	0	0	10624	2400
29/03/05	0	0	0	0	71084	17677
0.75m						
21/09/04	0	0	0	0	0	0
25/10/04	0	0	0	0	2	3
29/11/04	0	0	0	0	0	0
04/01/05	0	0	0	0	133	11
07/02/05	0	0	0	0	128	95
29/03/05	0	0	0	0	234	463
1.5m						
21/09/04	0	0	0	0	0	0
25/10/04	0	0	0	0	0	2
29/11/04	0	0	0	0	2	1
04/01/05	0	0	0	0	19	17
07/02/05	0	0	0	0	57	100
29/03/05	0	0	0	0	0	44

Table 7

2004-05 Numbers of *Lepioglyphus* / kg in six bins of rapeseed at ca.7% moisture content.

	1 1g/ kg	2 1g / kg	3 3g/kg	4 3g/kg	5 Control	6 Control
Surface						
19/08/04	1	1	1	1	1	1
21/09/04	1	2	1	0.1	60	354
25/10/04	33	1	0.1	0.1	1064	364
29/11/04	21	48	6	10	2586	5605
04/01/05	297	21	1	0.1	7590	6244
07/02/05	42	20	15	0.1	3400	5109
29/03/05	12	631	18	0	6860	6526
0.75m						
19/08/04	1	1	1	1	1	1
21/09/04	0.1	1	0.1	0.1	3	20
25/10/04	0.1	0.1	0.1	0.1	14	17
29/11/04	4	1	1	0.1	21	23
04/01/05	1	1	0.1	0.1	125	113
07/02/05	0.1	1	1	0.1	126	792
29/03/05	0	1	0	0	190	672
1.5m						
19/08/04	1	1	1	1	1	1
21/09/04	1	0.1	0.1	0.1	1	10
25/10/04	2	0.1	0.1	1	15	9
29/11/04	1	0.1	0.1	1	19	18
04/01/05	0.1	0.1	1	0.1	86	77
07/02/05	1	0.1	0.1	0.1	52	356
29/03/05	1	2	1	2	150	87

Table 8

2003-04 Numbers of predators (*Cheyletus*, gamasids) in six bins of rapeseed at ca.9% moisture content.

	1 Control	3 Control	4 1g/kg	5 1g/kg	2 3g/kg	6 3g/kg
Surface						
6/10/03	0	0	0	0	0,17	0
10/11/03	0,13	0	0	0	0	00
8/12/03	0	0	0	0	0,128	0,1
19/1/04	0,32	0	0	0	0,32	1,0
16/2/04	0,160	0	0	0	0,896	0
22/3/04	0,128	0	0	0	0,64	0
1.0m						
6/10/03	0	0	0	0	0,4	0
10/11/03	0,24	0	0,1	0	0.80	0,4
8/12/03	2,4	0	0,32	0	0,192	0,9
19/1/04	0,1	0	0	3,0	0,72	0,3
16/2/04	0,1	0	0	0	0,32	0,10
22/3/04	32,0	0	0	0	0	0,19
2.0m						
6/10/03	0	0	0	0	0,2	0
10/11/03	0,2	0	0	0	0,8	0
8/12/03	1,0	0	0,2	0	0,128	0,59
19/1/04	0	0	0	0	0,1	0,8
16/2/04	0	0	0	0	0,64	0,2
22/3/04	0	0	0	0	0,16	0

Table 9

2004-05 Numbers of predators (*Cheyletus*, gamasids) in six bins of rapeseed at ca.7% moisture content.

	1 1g/ kg	2 1g / kg	3 3g/kg	4 3g/kg	5 Control	6 Control
Surface						
21/09/04	0	0,1	0,0	0,0	1,0	23, 2
25/10/04	19,0	9,0	0,0	0,0	76,10	12,4
29/11/04	13,0	14,0	2,0	2,0	24,24	112,8
04/01/05	18,0	11,0	0.0	0,0	128,136	21,5
07/02/05	12,0	11,0	0,0	1,0	38,72	16,40
29/03/05	0,0	2,0	0,0	0,0	35,70	168,0
0.75m						
21/09/04	0,0	1,0	0,0	0,0	1, 0	0,0
25/10/04	0,0	0,0	0,0	0,0	3,0	1,0
29/11/04	3,1	1,0	0	2,0	0,0	5,0
04/01/05	4,0	0,0	0,0	0,0	0,0	2,0
07/02/05	0,0	0,0	0,0	0,0	0,0	8,5
29/03/05	0,0	0,0	0,0	0,0	0,0	17,9
1.5m						
21/09/04	0,0	0,0	0,0	0,0	0,0	0,0
25/10/04	0,0	0,0	0,0	1,1	3,0	0,0
29/11/04	4,0	2,0	0,0	0,0	0,1	3,0
04/01/05	2,0	1,0	0,0	0,0	0,1	2,0
07/02/05	1,0	0,0	0,0	0,0	0,0	0,0
29/03/05	0,0	0,0	0,0	0,0	0,2	1,0

Table 10

2003-04 Free fatty acid levels (%) in six bins of rapeseed at ca.9% moisture content.

	1 Control	3 Control	4 1g/kg	5 1g/kg	2 3g/kg	6 3g/kg
Surface						
Initial	0.33	0.21	0.23	0.26	0.39	0.31
6/10/03	0.9	0.72	1.5	1.92	2.62	3.38
22/3/04	0.92	0.67	1.87	1.51	3.12	1.82
1.0m						
Initial	0.33	0.21	0.23	0.26	0.39	0.31
6/10/03	0.6	0.42	0.48	0.52	1.32	1.27
22/3/04	0.56	0.32	0.47	0.61	1.91	1.07
2.0m						
Initial	0.33	0.21	0.23	0.26	0.39	0.38
6/10/03	0.41	0.54	0.59	0.48	0.91	1.45
22/3/04	0.52	0.50	0.49	1.47	1.35	1.38

Table 11

2004-05 Free fatty acid levels (%) in six bins of rapeseed at ca.7% moisture content.

	1 1g/ kg	2 1g / kg	3 3g/kg	4 3g/kg	5 Control	6 Control
Surface						
21/09/04	0.78	0.86	1.63	0.86	1.91	1.39
29/11/04	1.14	1.20	3.57	1. 57	1.40	1.25
29/03/05	0.56	0.60	0.59	0.50	0.65	1.08
1.0m						
21/09/04	0.78	0.86	1.63	0.86	1.91	1.39
29/11/04	1.66	1.49	1.52	1.83	1.50	0.96
29/03/05	0.56	0.54	0.61	0.58	0.69	1.02
2.0m						
21/09/04	0.78	0.86	1.63	0.86	1.91	1.39
29/11/04	0.72	1.32	1.57	1.53	1.68	0.80
29/03/05	0.61	0.56	0.50	0.48	0.60	0.78

Table 12

2003-04 Storage fungi (colony forming units /g) in six bins of rapeseed at ca. 9% moisture content.

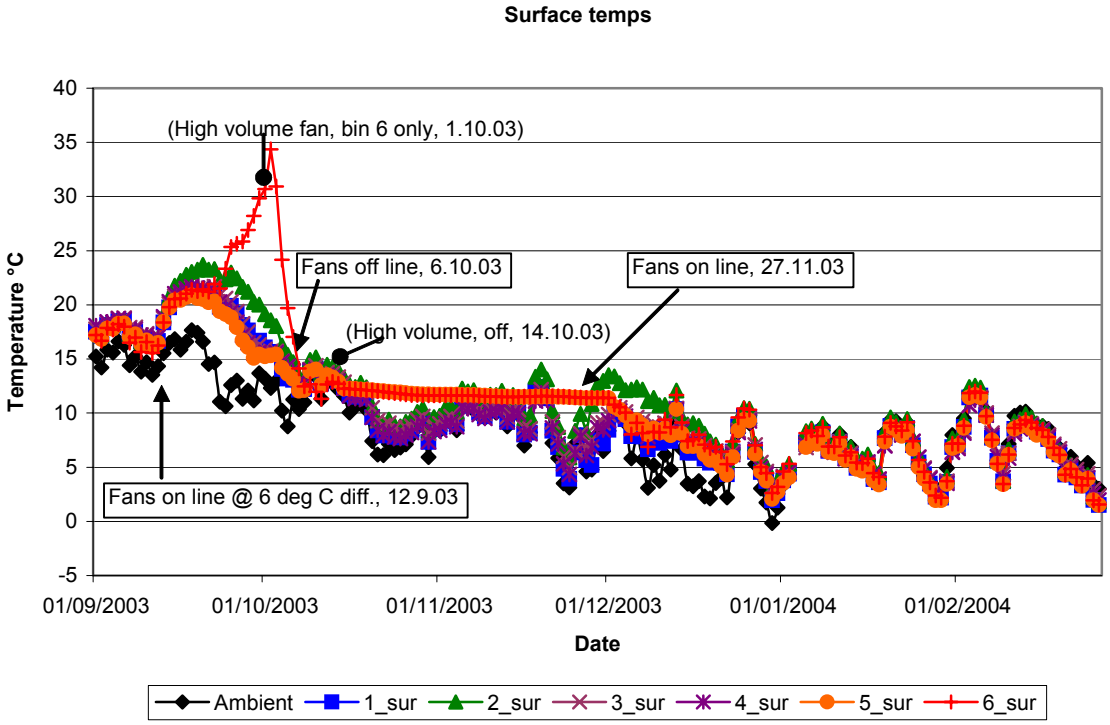
	1 Control	3 Control	4 1g/kg	5 1g/kg	2 3g/kg	6 3g/kg
1.0m						
6/10/03	120	20	3,330	0	0	0
22/3/04	1,300	900	3,400	2,000	37,000	55,270
2.0m						
6/10/03	60	0	90	10	60	30
22/3/04	11,140	1,140	4,300	6,300	23,570	53,840

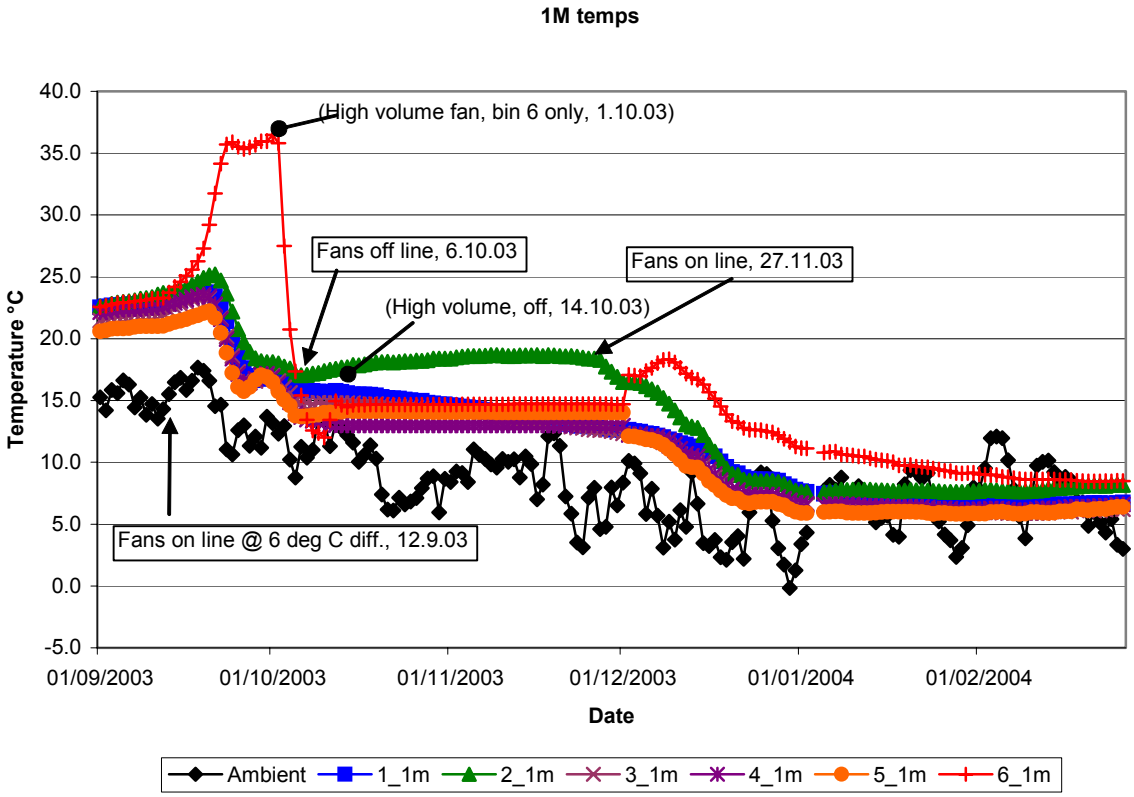
Table 13

Mean % mortality, numbers of F_1 insects and mean % population inhibition (with ranges).

Bin No.	Treatment	% Mortality	Nos. F_1 insects	% pop. inhibition
1	Control	0.9	61.2 (53-70)	0
3	Control	0.8	48.4 (33-78)	0
4	1 g/kg	11.4	17.4 (7-36)	68.2 (34.3 - 87.2)
5	1 g/kg	19	1.8 (0-5)	96.7 (90.9 - 100)
2	3g/kg	7.2	13.2 (5-20)	75.9 (63.5 - 90.9)
6	3 g/kg	14.3	1.4 (0-2)	97.4 (96.4 - 100)

Fig. 1. 2003- 4 Temperatures in six bins of rapeseed at ca 9% m.c..





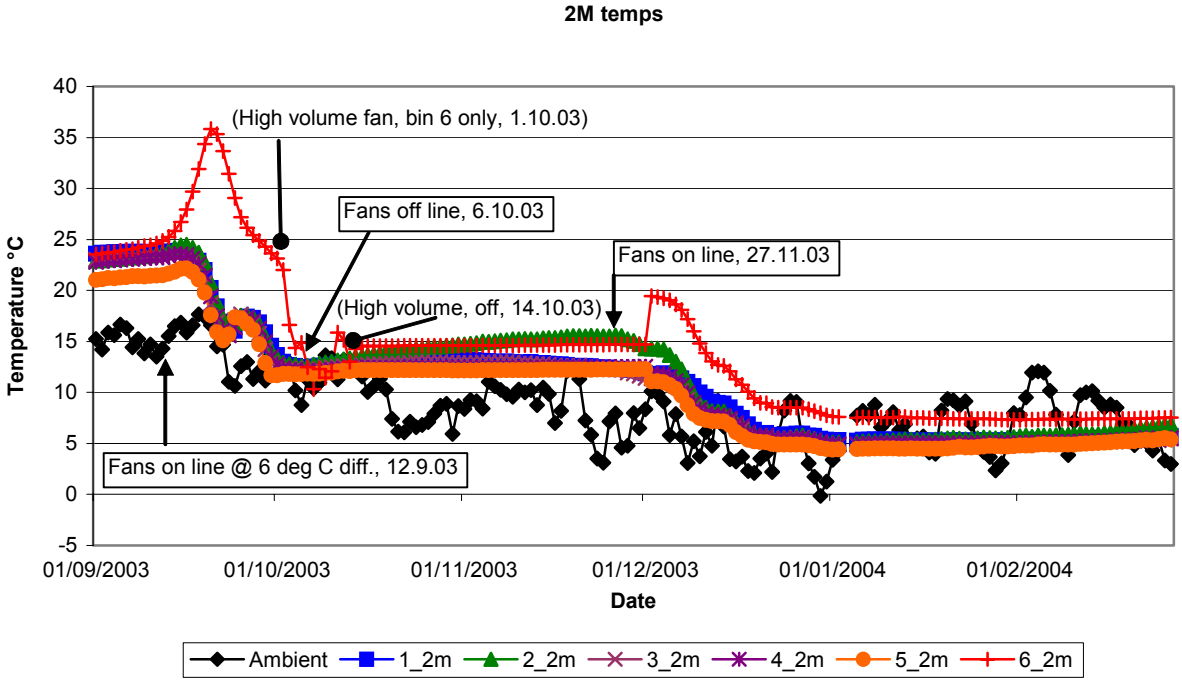

2M temps
(High volume fan, bin 6 only, 1.10.03)
Fans off line, 6.10.03
Fans on line, 27.11.03
(High volume, off, 14.10.03)
Fans on line @ 6 deg C diff., 12.9.03
Temperature °C
40
35
30
25
20
15
10
5
0
-5
01/09/2003
01/10/2003
01/11/2003
01/12/2003
01/01/2004
01/02/2004
Date
Ambient
1_2m
2_2m
3_2m
4_2m
5_2m
6_2m

Fig 2. 2003-4. Hours blown and ambient temperatures in six bins of rapeseed at ca. 9% m.c..

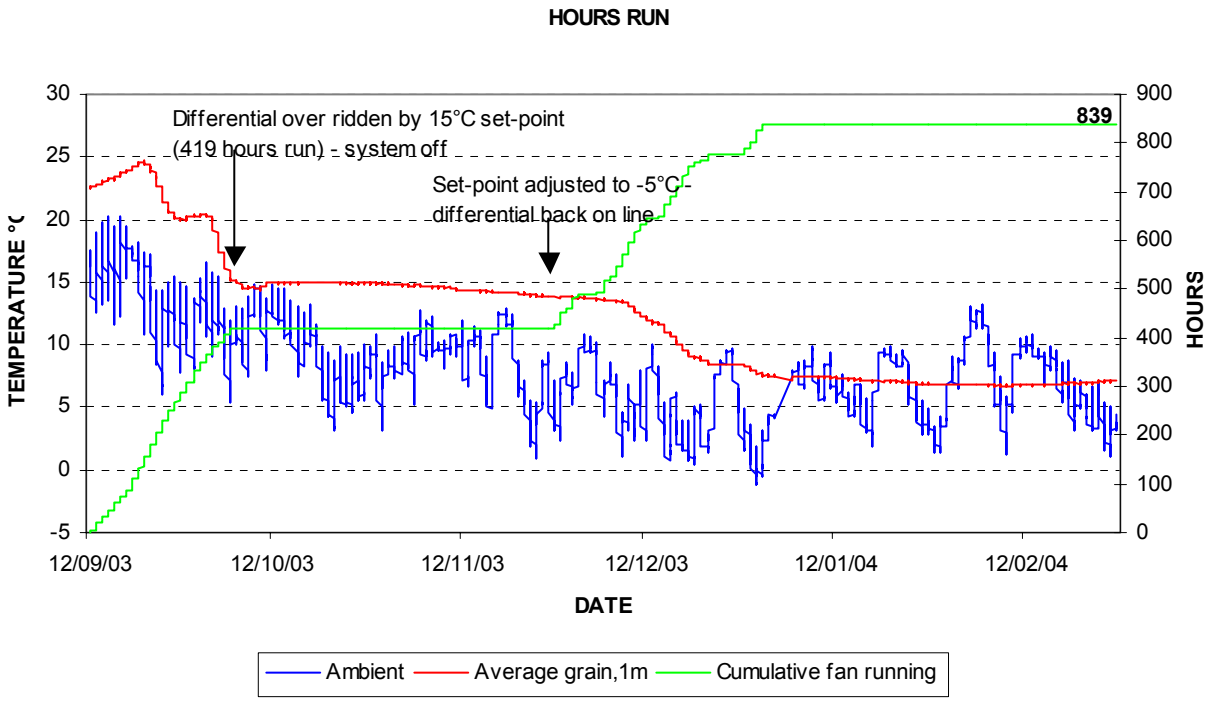
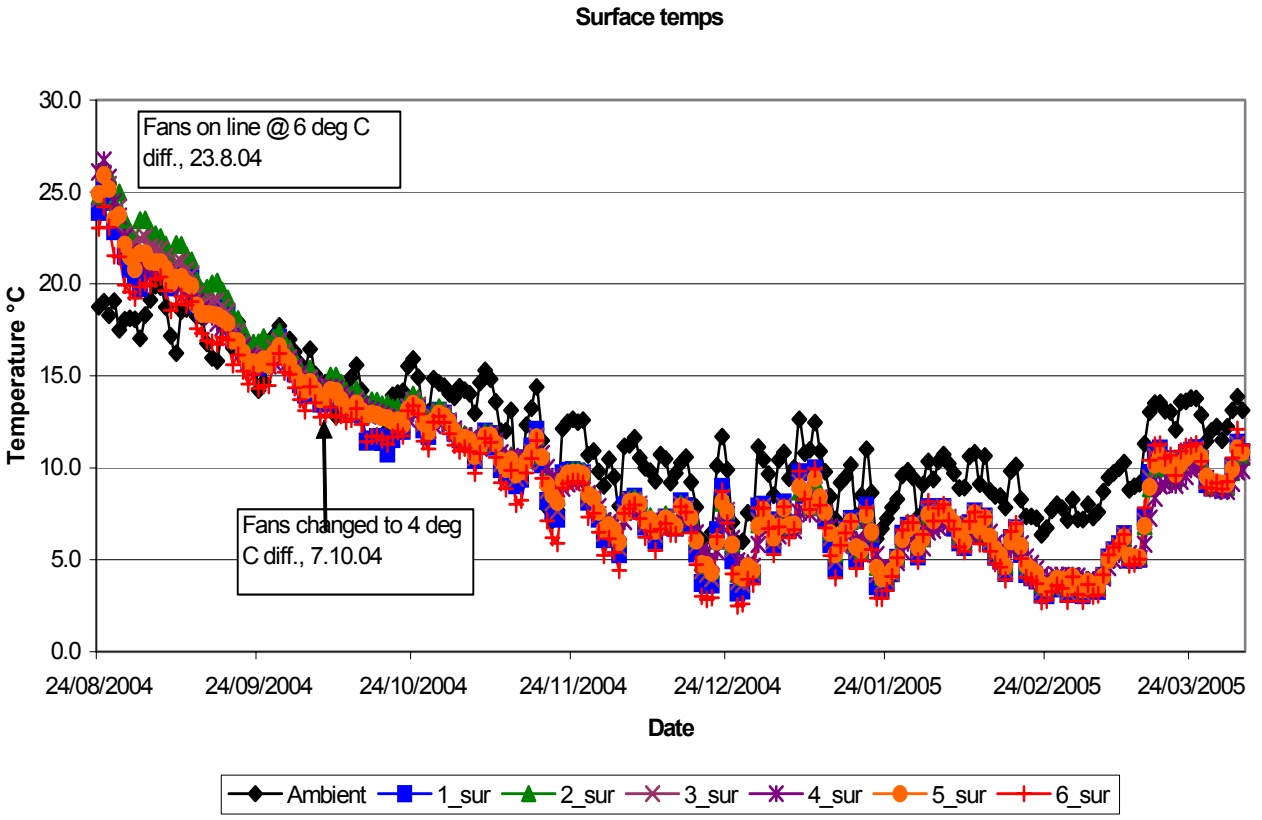


Fig 3. 2004-5. Temperatures in six bins of rapeseed at ca 7% mc.



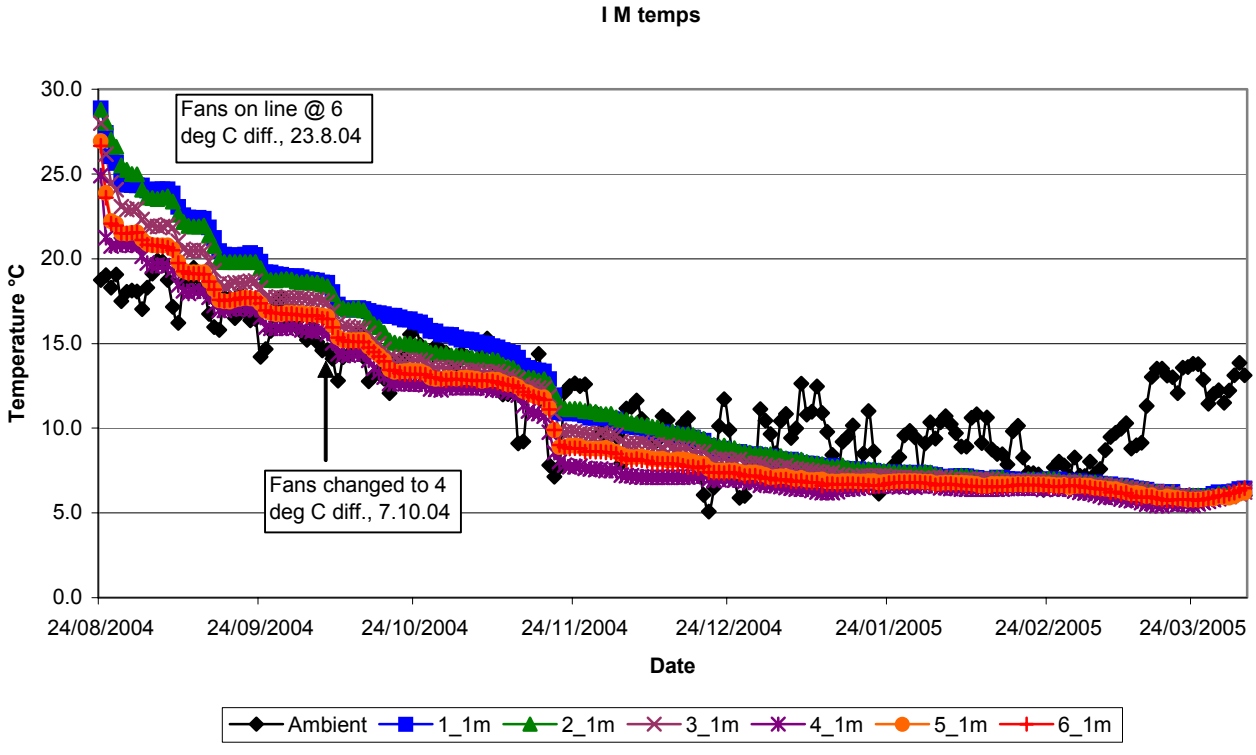


Figure 3. (continued)

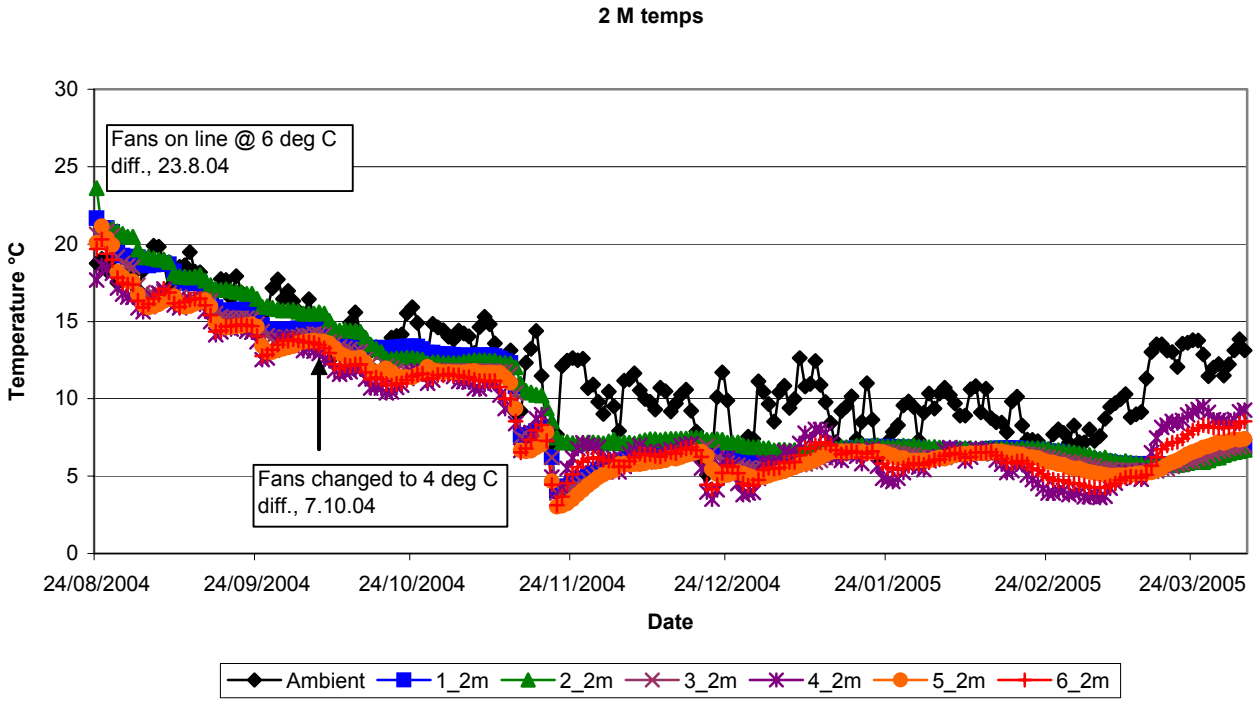


Fig 4. 2004-5. Hours blown and ambient temperatures in six bins of rapeseed at ca. 7% mc.