MANAGING RESISTANCE TO PHOSPHINE IN INSECT PESTS OF STORED CEREAL GRAIN IN AUSTRALIA

Patrick J. Collins
Department of Agriculture, Fisheries and Forestry Queensland, Australia

Presence of insect pests in stored cereal grain threatens both the security of the commodity and its acceptability to markets. Since at least the mid-1990s, fumigation with phosphine has been a key component of the management of these pests in Australia. Until very recently, however, there has been no practical alternative to this fumigant. It was recognised that a grain protection strategy based on the almost sole reliance on one chemical treatment could be seriously jeopardised if any target species developed resistance. Moreover, low level resistance was already known in Australia and higher levels of resistance had been reported overseas. The threat of high level resistance motivated the implementation of a national program that surveyed resistance to phosphine in the major grain growing regions in Australia annually. The survey method was to expose field-caught insects to two discriminating dosages of phosphine: a lower dosage that separated resistant from susceptible insects and a higher dosage that discriminated between known, low levels of resistance and any new, higher level resistance. Using these methods, the program provided early warning of the development of high level (Strong) resistance to phosphine in the lesser grain borer in 1997, the red flour beetle and sawtoothed grain beetle in 2000, the rusty grain beetle in 2007 and the rice weevil in 2012. Of these the most widespread and troublesome resistances have been those developed by the lesser grain borer and the rusty grain beetle.

Once resistance had been detected in the lesser grain borer, research initially focused on assessing the likely impact of resistance to industry. Extensive laboratory experiments supported by field trials established that strongly resistant lesser grain borer could be controlled with phosphine by maintaining certain minimum concentrations for specified times. Changes to label rates were recommended for cylinder-based formulations but this was not necessary for aluminium phosphide formulations as these were already adequate. It is essential, however, that fumigations be undertaken in sealed, gas-tight storages so that the protocols could be followed. In many circumstances, it is also important that fumigant concentrations are measured to ensure that protocols are being met.

In addition, classical and molecular genetic research revealed that strong resistance to phosphine is controlled by two major genes, *rph1* and *rph2*, both of which are incompletely recessive. This means that for resistance to be fully expressed, an individual insect must be homozygous for both genes. Weak resistance is controlled by the *rph1* gene. By themselves, each gene provides a low level of resistance; however, when combined in the same individual, the two mechanisms synergise resulting in the Strong level of resistance. In our experience, Strong resistance begins to be detected in insect populations when Weak resistance can be detected in about 80% of insect population samples. Initial genetic research was undertaken on the lesser grain borer but subsequent studies of resistance in other species indicate a very similar pattern of resistance genetics.

Strong resistance in the lesser grain borer could be managed effectively with relatively small changes in fumigation protocols; however, this was not the case with Strong resistant rusty grain beetle. The Strong resistance genotype in this species is expressed as a phenotype with an extremely high level of tolerance to phosphine. The concentrations and exposure periods required for control are currently very difficult to achieve in many storage types. Effective management of this pest requires the use of alternative chemicals, in particular sulfuryl fluoride (SF), which has been registered for use on cereal grains in Australia. SF is used where an outbreak of phosphine-resistant rusty grain beetle has occurred, and as an alternative in a pre-arranged series of fumigations, for example as the last fumigation.

Changes to fumigation protocols have been incorporated into a national phosphine resistance management strategy. The strategy aims to 1: reduce selection pressure by limiting the number of fumigations, improving sanitation procedures and expanding use of grain cooling facilities, and 2: destroy resistance insects by undertaking fumigations only in sealed silos and at specified rates of phosphine, and by encouraging the use of alternative chemicals.

The major components of the strategy include:

1. Strict sanitation, expanded use of cooling
2. Limit phosphine fumigations to 3 per parcel of grain
3. Fumigate only in sealed silos
4. Use recommended concentrations and exposure periods for control of Strong resistant insects. Ensure fumigant concentrations are monitored.
5. Use alternative fumigants and protectants
6. Base fumigation decisions on monitoring insect populations (rather than following calendar based fumigations schedules)