SOIL-APPLIED CONTROLLED-RELEASE INSECTICIDE FOR WHITEGRUB CONTROL IN SUGARCANE: ISSUES AND DEVELOPMENTS

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Abstract
Operational and performance difficulties with controlled-release (CR) granular chlorpyrifos insecticide and its limitations for long-term control of whitegrub damage to Australian sugarcane are discussed. One application of CR granules into the furrow can control infestations for 2 or more years. Difficulty in achieving optimal placement and premature degradation of chemical are major issues. Potential for the CR control system to result in insecticide resistance and difficult control of species with higher natural tolerance of chlorpyrifos are major weaknesses. Limited area-wide control where there is a high proportion of old ratoons that are no longer protected encourages outbreaks to continue. Significance of these problems is exacerbated where the CR product is the only suitable, registered treatment option. New programs to develop more extensive pest management systems for use in conjunction with CR insecticide should limit the effect of these limitations. Instilling necessary change in attitude to risk and greater competence in pest management are the major challenges to implementing new tactics.

Introduction
More than 13 species of whitegrubs (Coleoptera: Scarabaeidae: Melolonthinae), known as canegrubs, are major pests of Australian sugarcane (Allsopp et al., 1993). Most are geographically isolated, but some fields can have two or more species. About 150 000 ha (K.J. Chandler, unpublished data) are prone to infestation. These soil-inhabiting larvae eat roots, reducing cane yield and sugar content. Damaged plants ratoon poorly, if at all, necessitating premature replanting.

Controlled-release (CR) insecticide (suSCon® Blue, 140 g/kg chlorpyrifos; CropCare Australasia, Brisbane) is registered to control damage by 11 whitegrub species. One row-band application in the planting furrow can control damage for 2 or more years (Hitchcock et al., 1984; Chandler et al., 1993; Allsopp et al., 1996; Chandler and Erbacher, 1997a). Control of six species has been excellent. Operational difficulties and performance constraints with CR insecticide, limitations of the CR option, and actions to overcome these problems are described.

Operational difficulties

Application
Positioning granules at the optimum depth to control whitegrubs is a major issue. A row-band of granules 150–200 mm wide, 150–200 mm below the soil surface, effectively controls all 11 species (CropCare Australasia, Brisbane). A row-band 100–120 mm deep was less effective than at 150 or 200 mm deep for controlling greyback canegrub [Dermolepida albohirtum (Waterhouse)] (Chandler and Erbacher, 1997a). However row-bands at 100–120 mm or 150 mm deep were equally effective against Antitrogus parvulus Britton (Allsopp et al., 1996). Side-dressed granule bands are far less effective than row-bands for controlling greyback canegrub (Chandler et al., 1993). Because chlorpyrifos bonds tightly to soil (Racke, 1993), and whitegrubs must be less than 4 mm from granules to receive a lethal dose (K.J. Chandler, unpublished data), granules must be positioned where there is the highest probability for contact with whitegrubs for the best possible control. Four considerations influence where, how and when to apply granules.

Firstly, soil type and drainage characteristics and soil-moisture, together, regulate depth of whitegrubs in the soil. Patterns of root loss (K.J. Chandler, unpublished data) indicate greyback canegrub live only 50–150 mm deep in slow-draining soil and/or during prolonged rainfall, and deeper (150 mm) in well-drained soil, and at 200–300 mm only during dry periods and/or when the only remaining food is at this depth. Thus, granules 150 mm deep exert consistent control of greyback canegrub damage in both wet and dry environments, whereas granules at 200–300 mm control more effectively under dry conditions than wet conditions (Chandler et al., 1993; Robertson and Walker, 2001).

Secondly, changing root-profiles between plant and ratoon crops can change the relative effectiveness of the position of the granules. Plant cane appears most sensitive to loss of roots from the base of primary shoots (usually 150–200 mm deep), particularly for ‘dry’ years and in well-drained situations. Ratoons develop shallower root profiles than plant crops, and are more sensitive to loss of roots at a higher level (100–150 mm). Thus, granules 150 and 200 mm deep gave equivalent control of greyback canegrub in plant crops, but granules 150 mm deep gave slightly superior control in first-ratoon crops (Chandler and Erbacher, 1997a).

Thirdly, the most effective depth for granules varies with differing development and movement patterns of the different whitegrub species. Thus

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A. parvulus larvae, which go deep into the soil during cooler months to moult, but otherwise move throughout the soil profile, are controlled equally well by granules positioned 150–250 mm deep at planting, or at 100–120 mm deep during 'at fill-in' operations (Allsopp et al., 1996). *Lepidiota frenchi* Blackburn and *L. consobrina* Girault are dormant in sub-soil during cooler months, and their most critical damage commences deep in the profile during the dry spring months, and both are reliably controlled with CR granules applied 150 mm deep 'at fill-in' (Hitchcock et al., 1984), or with granules applied 200 mm deep 'at planting' (K.J. Chandler, unpublished data). In contrast, efficiency of control for non-dormant greyback canegrubs varies with granule depth; for them, the most efficient compromise is to position granules 150 mm deep (Chandler and Erbacher, 1997a).

Fourthly, some application methods are inappropriate where depth of granules is critical for efficient function, but prevailing conditions may preclude operations as or when intended. Topography, soil type, and soil moisture regimes, and row-profiles varying between 150–300 mm of soil above sett-level, all influence the suitability of various options.

The four factors influence method and timing of application and efficacy of control and, ultimately, the degree of client satisfaction with both the product and advice on how to apply it. For example, with greyback canegrub, row-banding 'at-planting' is necessary where the sett-piece will be 150 mm deep in the finished row-profile. Row-banding into the open furrow 'at fill-in', after germination and tillering, is appropriate where the sett-piece will be >200 mm below the surface. However, for the majority where the sett-piece will be 150–200 mm deep, application is often compromised by operational preferences and convenience. To use 'at fill-in' methods and to comply with the specified 150 mm depth of application are often perceived as difficult. Commonly, 'at fill-in' applications result in granules being only 100 mm deep or less, which is above the critical zone for control. Under such conditions, growing practices may opt for 'at-planting' application, even if effectiveness is less-than-optimum. Other growers in 'dry' areas prone to greyback canegrub plus a winter-dormant species apply granules deep, by 'at-planting' methods, primarily to control the latter species.

Close cooperation between industry service providers and the supplier of suSCon® Blue has been necessary to keep users alerted to common problems with application and degradation, and this situation is unlikely to change. Alternatively, a new product needing less critical application, such as a systemic insecticide, may be less persistent, but more likely to cause problems of environmental contamination.

**Degradation**

Premature loss of chlorpyrifos from CR granules, associated with less-than-potential levels of chlorpyrifos in soil, is an increasing problem. Chandler (1998) demonstrated its association with rapid addition of pulverised limestone to soil. Other alkaline products, including MgO and filter-mud by-product applied as nutrients and/or to amend soil properties, have the same effect. Generally, these treatments raise pH(1/2O) to >6.0–6.5. Also, rapid degradation is almost universal where soil is naturally pH > 7.0. Enhanced microbial degradation (Robertson et al., 1998) contributes, but there is evidence (K.J. Chandler, unpublished data) that microbiological transformation of chlorpyrifos is not the primary cause of premature loss. This is compatible with known degradation pathways for chlorpyrifos. Racke (1993) reports rapid degradation in soil above pH6.5 primarily by abiotic 'surface catalysed hydrolysis associated with clay particles' to its pyridinol derivatives, along with 'microbial degradation of an incidental nature'. However, soil microorganisms are 'very important in complete mineralisation of the major soil metabolites'. Management alone may not resolve the conflict of interests between the agronomic need for soil amendment and loss of control of whitegrubs with CR chlorpyrifos. Thus, a compromise approach was taken.

Chandler et al. (1998) showed loss from CR granules, and increased chlorpyrifos in soil around granules to 'expected' levels by zonal acidic amendment of the row-band. At soil pH > 7.0, 250 kg/ha ammonium sulfate and/or 150 kg/ha sulfur powder applied in the row-band with CR granules result in effective whitegrub control in the plant crop. However, these treatments do not usually prolong control into the ratoon crop (R.F. Cocco and A. Horsfield, BSES, Ayr; K.J. Chandler, unpublished data). Sulfur-coating retains far more chlorpyrifos in granules and soil than the zonal acidification process (Chandler et al., 1998). Field-trials indicate control into a second year with a new sulfur-coated CR product in soils where control was previously impossible (CropCare Australasia, Brisbane; K.J. Chandler, unpublished data).

**Current limitations of the CR system, and possible solutions**

**Unprotected ratoons**

A large proportion of unprotected crops predispose districts to persistent and uncontrollable damage by greyback canegrub. Ratoons in which CR granules are no longer effective are most at risk. It is possible to row-band CR chlorpyrifos granules into ratoons, to specifications given earlier (K.J. Chandler, unpublished data), but excessive cost precludes re-treatment of all old ratoons. Also, continued re-application of one product encourages microbiological degradation. Thus, alternative chemicals and formulations are being investigated as the main response to the need to protect ratoons.

**Resistance to chlorpyrifos?**

Controlled-release systems create high probability for the development of resistance (Roush and Daly, 1990). A bioassay with 5 μL droplets of chlorpyrifos injected into soil was developed to measure the susceptibility of whitegrubs (Chandler and Erbacher, 1997b). Data are used primarily to distinguish possible insecticide resistance from other factors that
contribute to control failure. The method mimics at least one mode of insecticide exposure around CR granules, on the assumptions (Roush and Miller, 1986) that similarity to the field increases the test’s reliability for diagnosing resistance or attributing poor control to other causes. Also, ‘ecologically realistic’ data could help to interpret control processes, perhaps leading to greater efficiency with this or a new CR product.

There is no evidence yet of insecticide resistance (Chandler and Erbacher, 1997b), and further tests are carried out annually. Susceptibilities of 10 species suggest that the method reflects the relativity of field control of each. Firstly, suSCon® Blue is not registered to control the most tolerant species, Lepidota noxia Britton, because of poor field control. The greatest instance of control ‘failures’ is associated with the second most tolerant species, D. albohirtum. Finally, few instances of weak control have been associated with the four least tolerant species, Antitrogus consanguineus (Blackburn), A. rugulosus (Blackburn), Lepidiota frenchi and L. negatoria Blackburn.

Susceptibility data, the control process, and performance criteria for CR granules

Interpretation of control processes using susceptibility data seems realistic. For example, the 51–85 µLD50 for D. albohirtum in soil (Chandler and Erbacher, 1997b) is also the maximum amount of chlorpyrifos around a granule under ‘ideal’ conditions (K.J. Chandler, unpublished data). However, if mortality were due only to contact with contaminated soil, then there is inconsistency with how the (apparent) minimum effective dose around granules (20 µg per granule; Chandler and Erbacher, 1997a) could kill 83 ± 12% [mean ± SE (mean); n = 12 measurements in Chandler et al. (1993)] of greyback canegrubs. This suggests there may be another, more lethal, mechanism killing greyback canegrubs, and mandible marks on granules adjacent to a high proportion of lethally poisoned greyback canegrubs (K.J. Chandler, unpublished data) suggest contamination due to oral manipulation of CR chlorpyrifos granules, but not from ingestion of granule particles. This apparent ‘lure’ effect suggests the possibility of alternative granule compositions and functions, on which to develop new or more efficient alternative products to control this species.

Alternative tactics or adjuncts to the CR control system

Control based on a single CR insecticide product has been remarkably successful. Despite limitations of high cost and inflexibility of the product, and considerable expenditure by sugarcane industry bodies and product manufacturers, few alternatives are available. Thus, the industry needs to ensure continued function and commercial availability of the current CR insecticide. However, advantages of having a diverse array of controls have been identified, and integrated crop and pest management options established to guide future research and systems development (Robertson et al., 1995; Samson et al., 1998). These programs combine modified cultural practices, with use of natural and artificially-cultured biological controls, and newer insecticides and formulations. Controlled-release insecticides retain integral roles within this framework.

Making more efficient use of the current CR product has high priority. A new strategy based on the ‘trap-crop’ tactic for aggregating egg-laying beetles into restricted ‘trap’ areas scheduled for insecticide treatment shows promise for increasing cost-efficiency of control of greyback canegrub with CR insecticide. Ward and Cook (1996) showed that greyback canegrub damage is usually aggregated into those crops that are tallest when beetles are flying. On one farm, 67 ± 9% [mean ± SE(mean); range 22–92%; n = 7 transects] of the greyback canegrub population was aggregated into ‘trap’ portions occupying 23 ± 4% of the area (personal communication, D. Logan, BSES, Ayr). Again, 91% of insects in two other cases were aggregated into 9% of the total area (K.J. Chandler, unpublished data). Restricting CR treatment to ‘trap’ areas, in either plant or ratoon crops, would reduce damage and insecticide use and cost, while increasing the proportion of those farms with some form of protection from damage.

However, the greatest challenge to the Australian industry is to develop major change in farmers’ attitudes to risk and to develop their competence and confidence in pest management systems. Both are necessary if more complex pest management programs are to substitute for what seems to be a simple, single-issue program solely dependent on CR insecticide.

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REFERENCES


L’INSECTICIDE A EMISSION LENTE APPLIQUE AU SOL POUR LE CONTROLE DU VER BLANC DANS LA CANNE A SUCRE: PROBLEMES ET DEVELOPPEMENTS

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Résumé
Les difficultés d’opération et de performance rencontrées avec l’insecticide granulé chlorpyrifos à émission lente et son action limitée pour le contrôle à long-terme des dégâts causés à la canne à sucre par le ver blanc en Australie, sont discutées. Une application de ces granules dans le sillon peut contrôler les infestations pendant au moins deux ans. Les contraintes majeures sont la difficulté à trouver le placement optimal du produit et sa dégradation prématurée. Les principales faiblesses sont le potentiel de ce système de contrôle à générer une résistance à l’insecticide et la difficulté de contrôler les espèces ayant un seuil de tolérance naturelle plus élevé au chlorpyrifos. Le contrôle limité sur une base régionale où la proportion de vieilles repousses, qui ne sont plus protégées, est élevée, favorise la recrudescence du ravageur. Ces problèmes sont d’autant plus graves quand le produit est la seule option appropriée qui soit homologuée. De nouveaux programmes, visant à développer des systèmes de contrôle plus extensifs, pour être utilisés en conjonction avec les insecticides à émission lente, devraient permettre d’obvier à ces restrictions. Les défis majeurs dans l’application de ces nouvelles techniques, consistent à inculquer un changement d’attitude quant aux risques et une plus grande compétence dans le domaine du contrôle des ravageurs.

Mots clés: chlorpyrifos, sensibilité, placement, dégradation, culture-piège.
APLICACIÓN AL SUELO DE UN INSECTICIDA DE LIBERACIÓN CONTROLADA
PARA EL CONTROL DEL GUSANO BLANCO EN CAÑA DE AZÚCAR: AVANCES
Y ALTERNATIVAS

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Resumen
Se analizan las dificultades tanto operacionales como de comportamiento del insecticida granular clorpirifos de liberación controlada (LC), al igual que sus limitaciones para el control a largo plazo del daño ocasionado por el gusano blanco en la caña de azúcar de Australia. Una aplicación de gránulos de LC en el surco pueden controlar las infestaciones por un período de dos años o más. Dos problemas importantes son la dificultad de lograr una ubicación óptima y una degradación prematura del insecticida. Sus mayores debilidades residen en la posibilidad de desarrollo de resistencia al sistema de LC y en la dificultad de controlar especies con una mayor tolerancia natural al clorpirifos. La presencia de áreas limitadas donde existe una alta proporción de socas viejas, favorece que continúen los brotes de la plaga. Estos problemas se ven agravados en sectores donde la única opción de manejo registrada es el uso del insecticida con LC. El desarrollo de nuevos programas de manejo más extensivos de la plaga en combinación con el empleo del insecticida con LC deben de reducir el efecto de estas limitaciones. Los retos más importantes para desarrollar nuevas tácticas se relacionan con inocular un cambio de actividad hacia el riesgo y una mayor efectividad en el manejo de la plaga.

Palabras claves: Clorpirifos, susceptibilidad, ubicación, degradación, cosecha-tampa.