

Industry Biosecurity Plan for the Grains Industry Threat Specific Contingency Plan

May beetle *Phyllophaga* genus

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1 Purpose of this Contingency Plan

This Contingency Plan provides background information on the pest biology and available control measures to assist with preparedness for an incursion into Australia of May beetle (*Phyllophaga* genus). It provides guidelines for steps to be undertaken and considered when developing a Response Plan to this pest. Any Response Plan developed using information in whole or in part from this Contingency Plan must follow procedures as set out in PLANTPLAN and be endorsed by the National Management Group prior to implementation.

2 Pest information/status

2.1 Pest Details

2.1.1 General information

Taxonomic position – Class Insecta; Order Coleoptera; Family Scarabaeidae; Subfamily Melolonthinae; Genus *Phyllophaga* Harris, 1827.

Phyllophaga is a very large genus (more than 260 species) of New World scarab beetles in the subfamily Melolonthinae. Common names for this genus and genera of the subfamily are May beetles, June bugs and June beetles (see Crop Protection Compendium 2008; www.nappfast.org).

Adult descriptions vary but most are heavy-bodied beetles with long spindly legs. They tend to be medium to large in size (8-25mm) and are blackish or reddish-brown in colour, without prominent markings. These beetles are nocturnal, attracted to lights in great numbers. The adults feed on the foliage of trees and shrubs and may cause significant damage when emerging in large numbers.

The insects pupate underground in the autumn and emerge as adults in the following spring. The larvae (called white grubs) feed on the roots of grasses and other plants. White grub is a general term given to the larval stage of many Scarabaeidae, particularly those in the sub-family Melolonthinae including the Japanese beetle (*Popillia japonica*), chafers (*Cyclocephala* spp.), *Ataenius* spp., and others which can cause damage to lawns. *Phyllophaga* larvae are “C” shaped and up to 25mm long, with cream coloured bodies and brown head capsules and dark internal markings on the end of the abdomen. They have three pairs of legs, one on each of their first three segments behind the head.

Larval infestations are greatly influenced by soil type or texture. Infestations of *Phyllophaga* spp. are reported to be more common in light, well-drained sandy soils than poorly drained, heavy clay soils.

Phyllophaga spp. attack maize, sorghum, soybean, wheat, rye, bean, oat, potato, turnip, cranberry, timothy, lespedeza, and other cultivated crops (EPPO Pest Risk Analysis 00/7909). They also infest various pasture grasses, lawns and nursery plantings. Seven species have specifically been reported as pests (*P. anxia*, *P. crinita*, *P. ephilida*, *P. fusca*, *P. implicita*, *P. menetriesii*, and *P. vicini*). Other species are likely to be pests of turf. As *P. crinita*, *P. implicita*, *P. menetriesii*, and *P. vicini* are known to be pests of maize and /or sorghum they are considered the highest potential risk to the Australian grains industry. It is important to note that because it is difficult to identify larvae to species level, many reports only refer to *Phyllophaga* spp. and for this reason it is difficult to have confidence in specific host relationships within this genus.

2.1.1.1 *Phyllophaga anxia* Leconte, 1850 (*Lachnosterna*)

Synonyms: *Lachnosterna dubia*, *Lachnosterna alpina*, *Ancylonycha brevicollis*, *Lachnosterna cephalica*, *Ancylonycha guadulpensis*, *Lachnosterna insperata*, *Ancylonycha puncticollis*, *Ancylonycha uninotata*

Common name: common June beetle (English); barbeau (French, Canada); cranberry white grub (English)

Distribution: Canada, United States

2.1.1.2 *Phyllophaga crinita* Burmeister, 1855 (Trichestes)

Synonyms: *Lachnosterna glabripennis*, *Listrochelus longiclavus*

Common name: June beetle

Distribution: Mexico, United States

Appearance: Adult: reddish-tan to brown and 12 -18mm in length. The pronotum is conspicuously hairy, but not or barely pruinose, the female pygidium is simple, the male antennal club is longer than the head (Fig. 1), and the male genitalia are diagnostic (Fig. 2). The leg claws have a pre-apical tooth (the tarsal claws each look like they have two teeth) (Thomas 2004).



Figure 1&2. *Phyllophaga crinita*, male, head and anterior body, lateral view. Note large antennal club and pubescence on pronotum. *P. crinita* male genitalia. Photographs by Jeffrey Lotz and M.C. Thomas, FDACS/DPI

2.1.1.3. *Phyllophaga ephilida* Say, 1825 (Melolontha)

Synonyms: *Lachnosterna burmeisteri*, *Ancylonycha laticeps*

Distribution: Canada, Mexico, United States

Common name: white grub

2.1.1.4 *Phyllophaga fusca* Froelich, 1792

Synonyms: *Lachnosterna fusca*, *Melolontha fervens*

Common name: northern June beetle (English); hanneton du nord (French, Canada)

Distribution: Canada, United States

2.1.1.5 *Phyllophaga implicita* Horn, 1887 (Lachnosterna)

Synonyms: *Phyllophaga linelli*, *Lachnosterna minor*

Common name: June beetle

Distribution: United States

2.1.1.6 *Phyllophaga menetriesii* Blanchard, 1851 (*Ancylonycha*)

Synonyms: *Phyllophaga setifera* var. *mentriesi*

Distribution: Colombia, Costa Rica, Guatemala, México, Panama

2.1.1.7 *Phyllophaga vicina* Moser, 1918 (*Lachnosterna*)

Distribution: Costa Rica, Guatemala, Panama

2.1.2 Life cycle

The biology of May beetles varies greatly due to the many different species. In general, adults emerge in the spring, mate and deposit eggs in a cell in the soil. Larvae hatch and develop through the summer and autumn. Larvae begin an upward migration through the soil in spring and a downward migration in autumn coinciding with changes in soil temperature. Larvae develop through 3 instars. Most species in the northern United States, including *P. implicita*, usually require 3 years to complete their life cycle, but may complete it in 2 years further south or under warmer soil conditions. The southern species such as *P. crinita* can complete development in one year. Pupation occurs in the soil.

2.1.2.1 Life cycle *P. crinita*

The life cycle for *P. crinita* is taken directly from the Texas A&M website (life cycle descriptions apply to the northern hemisphere) (<http://insects.tamu.edu/fieldguide/bimg139.html>).

Adults begin to emerge in spring. During periods of flight, large numbers of beetles can be attracted to lights. Peak flights occur in mid to late June in central Texas. Female adults, less attracted to lights, tunnel 5 to 12.5 cm into the soil to deposit their eggs. In 3 to 4 weeks, small grubs (larvae) hatch from eggs and develop through three stages (instars), with the first two stages lasting about 3 weeks. The last larval stage remains in the soil from autumn through spring. In spring and early summer, white grubs pupate 7.5 to 15 cm deep in the soil. Adults emerge from pupae in about 3 weeks. There is one generation per year, but in north Texas, development may take two years.

2.1.2.2 Life cycle *P. implicita*

The life cycle for *P. implicita* is taken directly from NDSU Insect Updates (northern hemisphere) - White Grub Management for North Dakota. Details were accessed from the NDSU websites (July 14, 2008) (<http://www.ag.ndsu.nodak.edu/aginfo/entomology/entupdates/whitegrub/whitgrub.htm>)

Phyllophaga implicita normally take three years to complete its life cycle. However, there is evidence that the life cycle can be shortened to two years when above average soil temperatures occur.

In the United States in May and June of the first year of the life cycle, beetles emerge and at night fly to trees to feed. Willow and poplar trees are the preferred hosts of *P. implicita* adults. After mating, females fly back to the fields from which they emerged and deposit 35 - 60 white eggs in the soil during the day. The highest density of eggs will be found in the soil near the adult food source, such as shelterbelts, the density declining with increasing distance from the trees. Eggs hatch in approximately 30 - 50 days, depending on soil temperatures. First instar larvae begin feeding on organic matter after hatching, later feeding on plant roots. Most larvae reach the second instar stage before soil temperatures begin to decline in autumn. With cooling soil temperatures, larvae descend into the soil profile where they spend the winter below the frost line.

In the spring of the second year, as soil temperatures increase, larvae begin their upward migration. In the United States most larvae do not reach the 0 to 15 cm soil layer until the last week of May. Larvae are expected to cause the greatest level of feeding injury in the second year of their life cycle. Larvae molt to the third instar by July and continue feeding throughout the entire summer in the upper 15 cm soil layer at the base of plants, until a severe frost occurs. At that time, the third instars descend in the soil profile to overwinter below the frost line.

In the third year, the larvae are found in the upper soil layers by early May. The larvae feed on seedling roots, but seldom cause significant stand losses. By early August, pupae and adults can be found at a soil depth of 15 to 45 cm. The next May and June the adults emerge, repeating the three year cycle.

During soil sampling in the late summer and autumn, all larval instars, pupae, and adults can be found. However, usually one brood dominates, representing the greatest proportion of the population for that period. As long as one brood dominates, significant feeding injury is expected only in one year out of three. The year of greatest injury should correspond with the second year of the life cycle, when second instars are the most numerous in the spring.

2.1.3 Dispersal

Even though adult *Phyllophaga* spp have functional wings capable of flight that could allow dispersal into new areas and new fields, they are considered weak fliers unlikely to cover great distances. Beetles emerge from the soil and fly at night, usually after significant rainfall or irrigation. Flight periods may last for several weeks, during which time mating and egg laying occur. The adults hide in the soil during the day and fly to trees to mate and feed at night. The females oviposit within a short distance of their food source.

2.2 Affected Hosts

2.2.1 Host range

Phyllophaga spp are polyphagous attacking a range of grasses, grain crops, beans and other cultivated crops. The adults of most species feed on deciduous trees with a smaller number feeding on coniferous trees. They are strongly attracted to fragrant flowers and ripe fruits. The preferred host of *P. implicita* adults are *Salix* spp. and *Populus* spp. Adults of *P. anxia* are reported in Quebec to feed on elm, oak, poplar, rose, aspen, ash, raspberry, willow, cherries, *Alnus*, walnut, birch etc and also on flower petals of plants such as apple and lilac (EPPO Pest Risk Analysis 00/7909). *P. crinita* adult feeding has not been well studied but has been listed on fact sheets as hardwood, broadleaf, or deciduous trees, and also mentioned as feeding on coniferous trees.

The larvae (white grubs) feed especially on the roots of fibrous-rooted plants whereas stronger tap-rooted plants are often tolerant to injury. *Phyllophaga* spp. attack maize, sorghum, soybean, wheat, rye, bean, oat, potato, turnip, cranberry, timothy, lespedeza, and other cultivated crops (EPPO Pest Risk Analysis 00/7909). They also infest various pasture grasses, lawns and nursery plantings.

P. ephilida is a pest of sweet potato (Diagne 2004). *P. anxia* is specifically reported as a pest of Fraser fir (*Abies fraseri*). In Canada, it is reported as mainly causing damage to potato but also attacks young pine, larch and oak plantings. *P. fusca* mainly attacks grasses and Fraser fir, whilst *P. implicita* mainly attacks maize and soybean. In south-eastern North Dakota, *P. implicita* is reported as causing damage to maize, wheat, oats, barley, sugar beet, soybeans and potatoes (NDSU Insect Updates). *P. menetriesii*, and *P. vicini* are reported as pests of maize in Costa Rica (King 1984), but little information is available on these species.

As *P. crinita*, *P. implicita*, *P. menetriesii*, and *P. vicini* cause damage to maize and /or sorghum they are considered the highest potential risk to the Australian grains industry.

2.2.2 Geographic distribution

Phyllophaga spp. are present in Central and North America. *P. anxia* and *P. fusca* are present in multiple states across the northern United States and Canada. *P. implicita* are more localised in the north-central states of the United States. *P. crinita* is found in northern Mexico and south-eastern United States. *P. menetriesii* and *P. vicini* are present in Central America.

2.2.3 Symptoms

Symptoms can be varied. Larvae eat the roots and may cause death of plants. The main symptoms are yellowing and wilting of the plants, mainly fibrous rooted plants such as grasses. Fraser fir seedlings for example, show yellowing of the needles then seedling death. In maize, *P. implicita* can cause seedling death and stunting. The year of greatest injury corresponds with the second year of the 3 year life cycle, when second instar larvae are the most numerous in the spring.

2.2.3.1 Sorghum

The most obvious and significant damage to sorghum occurs during spring soon after sorghum plants emerge from the soil. Seed germination occurs and a satisfactory stand is established, but resultant damage to roots by the larvae causing seedlings less than 15 cm tall to die. Stand losses can occur within seven to ten days after plants emerge in severely infested fields. It has been reported that one grub alone can destroy plants along 0.3 to 0.5 m of a row. Infested plants not killed as seedlings are severely stunted with many unable to produce grain. A third kind of damage is root pruning caused by overwintering and current-season larvae. Injured plants may produce panicles but do not have sufficient roots to prevent lodging (Teetes and Pendleton 1999).

2.3 Entry, establishment and spread

Pest significance: Medium

Some authors consider that white grubs are amongst the most destructive soil insects in North America. However in the literature, it is difficult to see the relative importance of these species. In Texas, where *P. crinita* is a pest of sorghum, it is only considered an occasional pest that causes economic damage in localized areas or only during some years. However, severe infestations can cause significant stand loss (Teetes and Pendleton 1999).

Entry potential: Low

The probability of entry for *Phyllophaga* spp. is rated as low as natural introduction is considered highly unlikely given that they have not spread from Northern America. It is very unlikely that *Phyllophaga* spp. will enter Australia by wind dispersal. Incursions through importation of commodities or through non-commodity pathways are unlikely for *Phyllophaga* spp. capable of infecting grain crops, given current quarantine procedures and lack of recorded incursions.

The most likely method of *Phyllophaga* spp. incursion into Australia is as a hitchhiker through the importation of commodities from the pest's host plants, and from regions in which *Phyllophaga* spp. is prevalent. The adults are relatively large and may be obvious in commodities. However, if individuals occur in low abundances in bulk cargo or bagged commodity, then detection may be difficult. Adult

females can survive up to 21 days without food (Chalfant et al 1990). Eggs and larvae are much smaller and may escape unnoticed, but are naturally only found in soil and not likely to be contained in commodities.

Establishment potential: High

Establishment potential is rated as high as the Australian climate is suitable for the establishment of *Phyllophaga* spp. in the cereal production regions of Australia. Although their pest potential is limited to a few crops they are generalist feeders that can survive on many grass (larvae) and deciduous tree (adults) species.

Spread potential: Medium

Phyllophaga spp. are generally considered weak fliers but can travel on the wind. Larvae may be transported in soil around the roots of plants for planting or on farming equipment, but are considered too large to be readily carried in traces of soil on vegetables. The climate of Australia is suitable for the spread of *Phyllophaga* spp. and coupled with the adults' ability to fly and their polyphagous feeding habits, the probability of spread for *Phyllophaga* spp is medium.

Natural spread would likely radiate slowly from the initial establishment, but could have multiple centres if larvae are being moved in association with host plant roots or adults are hitch hiking to new areas. For *P. implicita* there is a trend of decreasing larval density as distance from the shelterbelts increases with 99% or more of the larvae found within 118 m of the shelterbelts (Glogoza et al, 1998).

Economic impact: Low

Establishment of pest *Phyllophaga* spp. in maize or sorghum growing regions would likely cause some losses in grain production and increased expenditure on insecticides and other management practices. The host range affected by *Phyllophaga* spp. includes sorghum, maize, peanuts, soybean and sunflower. Yield losses attributed to *P. crinita* in Mexican corn fields ranged from 0.4 – 1.3 tonnes/ha (Villalobos, 1992). *Phyllophaga* larvae cause stunting, lodging, and death of seedlings in sorghum and maize and severe stand loss can occur if the infestation level is very high. It is usually only considered a secondary or occasional pest as noted above. Australian sunflower, sorghum and maize crops occasionally have establishment problems caused by the black sunflower scarab, a similar species (<http://www2.dpi.qld.gov.au/fieldcrops/8993.html>).

Environmental impact: Negligible

There is no or negligible potential to degrade the environment or otherwise alter ecosystems by affecting species composition or reducing the longevity or competitiveness of wild hosts.

Overall risk: Medium

The overall risk is considered to be medium.

2.4 Diagnostic information

2.4.1 Diagnostic protocol

Traditional taxonomic methods based on keys and descriptions are adequate for identification of *Phyllophaga* spp. adults. Larvae will require rearing to adulthood for species determination. Due to the variety of colour morphs, examination of an adult male specimen's genitalia is the only certain method of determination.

Phyllophaga larvae can be separated from other genera of "white grubs" by the pattern of the raster, the arrangement of bristles and hairs on the underside of the larvae.

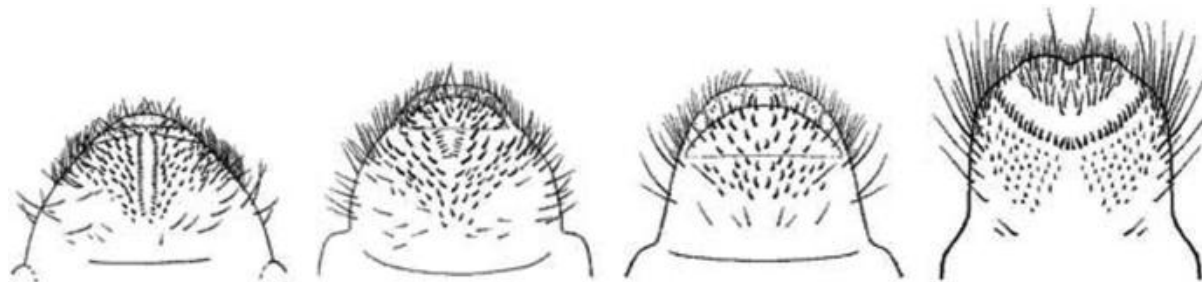


Figure 3. Raster patterns for (from left to right) *Phyllophaga* grubs, Japanese beetle (*Popillia japonica*) grubs, *Cyclocephala* grubs, and Asiatic garden beetle (*Maladera castanea*) grubs. (Illustrations from "Identification of White Grubs in Turfgrass," The Ohio State University FactSheet HYG-2510-94, author David J. Shetlar.)

The eggs of *Phyllophaga* spp. are oval to round, 1.5-3 mm in diameter and pearly white in colour. They later become darker before emergence (Selman 2008).

2.5 Response checklist

2.5.1 Checklist

Guidelines for Response Checklists are still to be endorsed. The following checklist provides a summary of generic requirements to be identified and implemented within a Response Plan:

- Destruction methods for plant material, soil and disposable items
- Disposal procedures
- Quarantine restrictions and movement controls
- Decontamination and farm cleanup procedures
- Diagnostic protocols and laboratories
- Trace-back and trace-forward procedures
- Protocols for delimiting, intensive and ongoing surveillance
- Zoning
- Reporting and communication strategy

Additional information is provided by Merriman and McKirdy (2005) in the Technical Guidelines for Development of Pest Specific Response Plans.

2.6 Delimiting survey and epidemiology study

Delimiting surveys should comprise local surveys around the area of initial detection concentrating on areas of susceptible crops and adult food sources. Surrounding crops would then be surveyed. The extent of the survey beyond the initial infected crop should be guided by the test results from surrounding crops.

Adult *Phyllophaga* beetles are relatively weak flyers and do not usually travel beyond 100m from a food source. They are strongly attracted to lights, both ultraviolet and incandescent, and pheromones are available for some pest species. Adults mainly fly in late spring and early summer, but some can be caught throughout summer. Light or pheromone traps would likely detect lower populations than soil samples and with less effort involved.

2.6.1 Sampling method

Light or pheromone traps should be placed in the area of initial detection as well as at a distance of 500m and 5km. Results from these traps would determine the need to expand the trapping grid. Traps should be located in areas near host plants. Traps should be checked at least every 2 weeks from October through January. Adult traps should also be used as part of a detection survey in the main growing regions of susceptible crops outside of the area of initial detection.

Field inspections should be conducted in late summer and autumn. The top 15cm of soil in a 50 x 50cm area should be checked from 30 sites. Sites should be taken along a transect that runs within 40m of shelterbelts, particularly shelterbelts containing deciduous trees. For the purpose of a delimiting survey, samples should be preferentially taken beneath plants that appear stunted or dying. Dead areas should not be sampled but live plants at the edges could be sampled.

Vacuum sampling or sweep netting of affected crops will not give adequate results for delimiting *Phyllophaga* spp. infestation.

Of the four life stages (egg, larva, pupa and adult) only adults are identifiable to species using morphological features. Larvae can be identified to genus. For diagnostic purposes, adults can be hand collected into glass vials. Larvae will need to be collected directly from the soil. Mature larvae for rearing to adults can be collected from soil and kept in rearing cages in a constant temperature room for regular checking. If sending live larvae they should be sent in association with the soil they were detected in. Care needs to be taken to prevent escape.

Adults and larvae can be preserved by placing in 70% ethanol and stored indefinitely, although their colour fades gradually with time. Specimens required for molecular diagnostic work should be killed and preserved in 100% ethanol or frozen (-80°C). No molecular diagnostic tests are available at this time.

Where possible it is advisable to collect a large number of specimens of all life stages. With adult stages collect a number of specimens of varying size and colour depicting variation in the morphology of the species. Collection of different life stages can assist in diagnosis. Also collect specimens in duplicate that are clean and in good condition i.e. that are complete with appendages such as antennae, wings and legs. Kill specimens by freezing for 24 hours. If live specimens need to be sent away for identification, carefully fold specimens in tissue paper and place in crush-proof plastic tube or container with several holes in the lid for ventilation. Label each sample clearly using an alcohol-proof marker. If possible retain and store a duplicate sample in a secure location.

2.6.2 Epidemiological study

The degree of spread would depend on the amount of time (in years) the pest was present prior to detection. Due to its long life cycle (1-5 years per generation), and the low fecundity (20-50 eggs per female) the intrinsic rate of increase would be low. The overwintering mortality of *P. implicita* is estimated to be 30% in North Dakota. The natural dispersal of *Phyllophaga* is also limited as females tend to lay eggs in close proximity to their food source. It is unknown how far adults will travel to find a food source, but because they are weak fliers it is unlikely that it would be over a great distance.

2.6.3 Models of spread potential

The rate or potential for spread has not been studied for *Phyllophaga* spp. *P. implicita* tends to deposit eggs only within a short distance from the adult food source with at least 90% of larvae detected within 55 m of the shelterbelts and 99% or more of the larvae found within 118 m of the shelterbelts (Glogoza et al, 1998).

2.6.4 Pest Free Area (PFA) guidelines

Pest free area guidelines relevant to this pest. Points to consider are:

- Design of a statistical delimiting field survey for the presence or absence of *Phyllophaga* adults or nymphs.
- Light and/or pheromone traps should be used to monitor for adults.
- Plant and soil sampling using appropriate diagnostic tests.

2.7 Availability of control methods

2.7.1 General procedures for control

- Minimise adult food sources (particularly deciduous hardwoods) near susceptible crops.
- Adopt best-practice farm hygiene procedures to retard the spread of the insect between paddocks and adjacent farms. Do not move soil from infested paddocks to non-infested paddocks.
- Crop rotation: Although *Phyllophaga* larvae are capable of feeding on a wide range of plants, they cause more damage to monocots. Planting susceptible crops such as sorghum in a field where a non-grass crop (eg not cereals or pasture) was grown in the previous year is considered the most important cultural management tactic against white grubs (Teetes and Pendleton 1999).
- Monitoring: As larvae overwinter and are therefore present in the soil when the crop is planted, the presence of larvae should be determined before sowing. Larvae are present in the upper 15 cm of soil until a killing frost occurs in the autumn. In the spring, larvae return to the upper soil layers. The exact time they return is not predictable and may be after susceptible crops have already been planted. Effective control measures cannot be applied after the crop is planted. In the United States, it is recommended to sample during late summer and autumn before a freeze occurs, however this may not be applicable under Australian conditions. Determine the presence or absence of white grubs in the soil by using a shovel to evacuate a 32 x 32cm area (1 sq foot) and then examine the soil for grubs (Teetes and Pendleton 1999).

- A germinating grain bait technique for monitoring soil pests of sorghum has been developed which could be applied to *Phyllophaga* spp. (Robertson & Simpson 1989): Immediately following planting rain:
 1. soak insecticide-free crop seed in water for at least 2 hours to initiate germination;
 2. bury a small handful of the seed at shallow depth and cover seed lightly with 1 cm soil;
 3. chose five widely spaced sites in each 100 ha; at each site, bury seed on the corners of a 5 m x 5 m square;
 4. check for seedling emergence - once emerged, leave seedlings overnight;
 5. dig up the entire plants the next day and put the plants on a tray to count insects.
- Pheromones have been determined for *P. anxia* and *P. crinita* (<http://www.pherobase.com>). The pheromone for *P. anxia* will also attract some *P. fusca*. Pheromones to date have not been used for control via mating disruption or attract and kill, but can be of use in monitoring.
- A threshold 0.5 - 1 larva per square foot is used in the U.S. for sorghum and maize. This is approximately 5 -10 per m² or 1.25- 2.5 per “50 x 50cm area” (the standard counting grid used in many Australian crops).
- Pre-sowing application of registered insecticides is effective but expensive because the insecticide must be broadcast and then incorporated into the soil (Teetes and Pendleton 1999).
- Suppression of white grub abundance can be achieved using an in-furrow or band application of insecticide at planting (Teetes and Pendleton 1999).
- There are no post-emergence insecticide applications effective as a rescue treatment if damage is seen as crops emerge.

2.7.2 Control if small areas are affected

As above

2.7.3 Control if large areas are affected

It is unlikely that large areas would be affected within the first 2-3 years of introduction due to the relatively slow natural dispersal of *Phyllophaga* spp. If infestations of *Phyllophaga* spp were to establish and remain undetected for a number of years, larger areas may be affected. In this scenario, attempts at eradication would likely be unfeasible given the broad host range, and control should centre on management of the incursion. There may be some scope for area wide management through cultural practices (see below), but due to the polyphagous nature of these beetles and the narrow range of crops that are likely to be economically damaged, crop specific management will be more practical.

2.7.4 Cultural control

Crop rotation is probably the most important cultural control. Susceptible crops such as maize and sorghum should be sown into paddocks that were planted to non-grass crops the previous season (for example, don't follow a cereal crop with maize or sorghum - see section 2.7.1).

Minimise adult food sources (particularly deciduous hardwoods) near susceptible crops. A number of studies have shown that crops more than 300m from the adult food sources of *P. implicita* are less likely to be infested (Glogoza et. al., 1998).

2.7.5 Host plant resistance

Sweet potato lines have been evaluated for resistance to *P. ephillida* with little success (Diagne 2004). Some promising results have been shown in turfgrass (Reinert & Read 2001), but no evidence was found for host plant resistance or tolerance in sorghum or maize.

2.7.6 Chemical control

A number of insecticides are recommended for control of *Phyllophaga* spp. in the United States. Insecticides used are either incorporated into the soil pre-sowing, applied as a band or applied in-furrow at the time of planting.

Chlorpyrifos is effective in the United States, and is registered in maize and sorghum in Australia. The North Dakota recommendation for control of *P. implicita* in maize is: Lorsban 4E (45% chlorpyrifos) applied at a rate of 2.4 fl oz/1,000 ft of row. Apply in a T-band or in-furrow in front of press wheels at planting time or at time of cultivation with no more than 30% cover of crop residue remaining on the soil surface. Use a minimum of 5 GPA. Not more than 1 application per season. Incorporate into top 0.5 to 1 inch of soil using chains or tines behind press wheel. REI = 24 hours (Knodel 2007).

Carbaryl is registered in Australia for control of the black sunflower scarab beetle, *Pseudoheteronyx* spp., in sunflower. The larvae of these beetles are also known as white grubs and can cause establishment problems in sorghum. See <http://www2.dpi.qld.gov.au/fieldcrops/3689.html> for management information. Carbaryl is registered in both sorghum and maize for other pests.

Seed treatments: Limited field tests suggest that imidacloprid and thiamethoxam (neonicotinoids) seed treatments can be effective. Seed treatments based on clothianidin (neonicotinoid) may also be effective, but are not currently registered in Australia.

2.7.7 Mechanical control

Cultivating and ploughing of soil in late spring or early autumn will destroy many larvae, pupae and adults in the soil and also exposes the insects to predators. For this cultural practice to be effective, cultivation must occur before the grubs migrate below the cultivation depth (Teetes and Pendleton 1999).

Trapping adults with light traps may be effective at lowering population levels, but it should be noted light traps tend to collect a greater proportion of males than females (Diagne 2004).

2.7.8 Biological control

Parasitic wasps that attack *Phyllophaga* spp. include *Pelecinus polyturator* and tiphiids in the genera *Tiphia* and *Myzinum*. Bombyliid and pyrgotid flies such as *Pyrgota undata* also parasitise *Phyllophaga* larvae. A survey in Quebec Canada found 29 species (belonging to 13 families in 3 orders) of parasitic and predaceous insects associated with *P. anxia*. Tachinid flies and tiphiid wasps were the most common parasites, but the survey showed that the natural enemies had low impact on field populations of the pest (Poprawski 1994). Importation of exotic natural enemies would probably be of limited value.

A number of pathogens have been associated with white grub larvae including *Bacillus cereus*, *Metarhizium anisopliae*, *Beauveria bassiana*, *Fusarium* sp., and *Penicillium* sp. (Diagne, 2004). In Quebec Canada, *M. anisopliae* and *B. bassiana* were potent pathogens of *P. anxia* (Poprawski and Yule 1991). *M. anisopliae* is considered as a promising biological control agent of *Phyllophaga* spp. (Rodriguez-Del-Bosque et al 2005). Australian isolates of *M. anisopliae* and *B. bassiana* have shown promise for control of scarabs in sugarcane (Milner et al. 1992). *P. anxia* naturally carries a virus

(*Phyllophaga anxia* iridescent virus, PaIV) which has little significance in nature (Poprawski 1994). The fungus *Cordyceps* also infects white grubs reducing populations (Selman 2008).

3 Course of Action – Eradication Methods

3.1 Destruction strategy

3.1.1 Destruction protocols

- Disposable equipment, infected plant material or soil should be disposed of by autoclaving, high temperature incineration or deep burial. Any equipment removed from the site for disposal should be double-bagged.
- Herbicides could be used to destroy the infected crops or pastures.
- Infected crops or pastures could be ploughed in.
- Insecticides could be used to destroy the pest.
- Farm machinery used in destruction processes need to be thoroughly washed, preferably using a detergent such as Decon 90.

3.1.2 Decontamination protocols

Machinery, equipment, vehicles in contact with infected plant material, soil or present within the Quarantine Area, should be washed to remove soil and plant material using high pressure water or scrubbing with products such as a farm degreaser, detergent like Decon 90 or a 1% bleach solution in a designated wash down area. General guidelines for wash down areas are as follows:

- Located away from crops or sensitive vegetation
- Readily accessible with clear signage
- Access to fresh water and power
- Site, including entry and exit points, should be mud free (e.g. gravel, concrete or rubber matting)
- Gently sloped to drain effluent away
- Effluent must not enter water courses or water bodies
- Allow adequate space to move larger vehicles
- Away from hazards such as power lines
- Waste water, soil or plant residues should be contained (see PLANTPLAN 2008 Appendix 18).
- Disposable overalls and rubber boots should be worn when handling infected soil or plant material in the field. Boots, clothes and shoes in contact with infected soil or plant material should be disinfected at the site or double-bagged to remove for cleaning.
- If hands, skin or hair have been in contact with infested plant material or soil they should be washed.
- Decon 90 (Enviroequip) is a suitable detergent for using to decontaminate equipment or personnel.
- All chemicals used according to label.

3.1.3 Priorities

Specific priorities for eradication

- Confirm the presence of the pest.
- Prevent movement of vehicles and equipment through affected areas.
- Priority of eradication/decontamination of infected host material.
- Control May beetles to prevent further spread.
- Inform all groups in the industry.
- Determine extent of infestation through survey.

3.1.4 Plants, by-products and waste processing

- Infected plant material should be destroyed by (enclosed) high temperature incineration, autoclaving or deep burial.
- Infected paddocks should be ploughed in to remove food and decrease larval survival (see 2.7.7).

3.1.5 Disposal issues

- Once introduced and established, *Phyllophaga* larvae can survive in soils for long periods, even in the absence of plant hosts and thus be difficult to eradicate.
- Particular care must be taken to minimize the transfer of infected soil from the area.
- Late spring or early autumn ploughing destroys many larvae, pupae, and adults in the soils and also exposes the insects to predators.
- There are no known issues with resistance of *Phyllophaga* spp. to chemicals or physical treatments.

3.2 Quarantine and movement controls

3.2.1 Quarantine priorities

- Soil at the site of infection to be subject to movement restrictions.
- Potted plants and turf should be subject to movement restrictions.

3.2.2 Movement control for people, plant material and machinery

Movement of people, vehicle and machinery, from and to affected farms, must be controlled to ensure that infected soil or plant debris is not moved off-farm on clothing, footwear, vehicles or machinery.

Examples of movement controls include:

- Signage to indicate quarantine area and/or restricted movement in these zones.
- Movement of plant material or soil by permit only.
- Hay should not be removed from the site as there is a low risk of moving adults.

Whilst the adults may be seen, adults and nymphs may still be present on vehicles and machinery used on the site. All machinery and equipment should be thoroughly cleaned down with a pressure cleaner prior to leaving the affected farm. The clean down procedure should be carried out on hard standing or preferably a designated wash-down area to avoid mud being recollected from the affected site onto the machine.

3.3 Zoning

The size of each quarantine area will be determined by a number of factors, including the location of the incursion, biology of the pest, climatic conditions and the proximity of the infected property to other infected properties.

3.3.1 Destruction zone

The entire crop or pasture should be destroyed after the level of infection has been established. The delimiting survey will determine whether or not neighbouring host crops are infected and need to be destroyed. The Destruction Zone may be defined as contiguous areas associated with the source of infestation (i.e. the entire trial, paddock or farm if spread could have occurred prior to the infestation being identified).

3.3.2 Quarantine zone

The Quarantine Zone is defined as the area where voluntary or compulsory restraints are in place for the affected property(ies). These restraints may include restrictions or movement control for removal of plants, people, soil or contaminated equipment from an infected property.

3.3.3 Buffer zone

A Buffer Zone may or may not be required depending on the incident. It is defined as the area in which the pest does not occur but where movement controls or restrictions for removal of plants, people, soil or equipment from this area are still deemed necessary. The Buffer Zone may enclose an infested area (and is therefore part of the Control Area) or may be adjacent to an infested area.

3.3.4 Restricted Area

The Restricted Area is defined as the zone immediately around the infected premises and suspected infected premises. The Restricted Area is established following initial surveys that confirm the presence of the pest. The Restricted Area will be subject to intense surveillance and movement control with movement out of the Restricted Area to be prohibited and movement into the Restricted Area to occur by permit only. Multiple Restricted Areas may be required within a Control Area.

3.3.5 Control Area

The Control Area is defined as all areas affected within the incursion. The Control Area comprises the Restricted Area, all infected premises and all suspected infected premises and will be defined as the minimum area necessary to prevent spread of the pest from the Quarantine Zone. The Control Area will also be used to regulate movement of all susceptible plant species to allow trace-back, trace-forward and epidemiological studies to be completed.

3.4 Decontamination and farm clean up

Decontaminant practices are aimed at eliminating the pest thus preventing its spread to other areas.

3.4.1 Decontamination procedures

General guidelines for decontamination and clean up

- Refer to PLANTPLAN (Plant Health Australia 2008) for further information.
- Keep traffic out of affected area and minimize it in adjacent areas.
- Adopt best-practice farm hygiene procedures to retard the spread of the pest between fields and adjacent farms.
- Machinery, equipment, vehicles in contact with infected plant material or soil or present within the Quarantine Area, should be washed to remove soil and plant material using high pressure water or scrubbing with products such as Decon 90 detergent, a farm degreaser or a 1% bleach solution in a designated wash down area as described in 3.1.2.
- Infested crops should be ploughed in when larvae are near the surface in late spring to early autumn. This practice may need to be repeated to remove volunteers and maximise mortality of *Phyllophaga* larvae (see section 2.7.7).
- A list of best-practice farm hygiene procedures to retard the spread of the pest between fields and adjacent farms.

3.4.2 General safety precautions

For any chemicals used in the decontamination, follow all safety procedures listed within each MSDS.

3.5 Surveillance and tracing

3.5.1 Surveillance

Detection and delimiting surveys are required to delimit the extent of the outbreak, ensuring areas free of the pest retain market access and appropriate quarantine zones are established.

Initial surveillance priorities include the following:

- Survey of all host growing properties in the pest quarantine area;
- Survey of all properties identified in trace-forward or trace-back analysis as being at risk;
- Survey of all host growing properties that are reliant on trade with interstate or international markets which may be sensitive to *Phyllophaga* spp. presence;
- Survey of commercial nurseries selling at risk host plants; and
- Survey of other host growing properties and backyards.

3.5.2 Survey regions

Establish survey regions around the surveillance priorities identified above. These regions will be generated based on the zoning requirements (section 3.3), and prioritised based on their potential likelihood to currently have or receive an incursion of this pest. Surveillance activities within these

regions will either: allow for the area to be declared pest free and maintain market access requirements; or establish the impact and spread of the incursion to allow for effective control and containment measures to be carried out.

Steps outlined below form a basis for a survey plan. Although categorised in stages, some stages may be undertaken concurrently based on available skill sets, resources and priorities.

Phase 1:

Identify properties that fall within the buffer zone around the infested premise.

Complete preliminary surveillance to determine ownership, property details, production dynamics and tracings information (this may be an ongoing action).

Phase 2:

Preliminary survey of host crops in properties in buffer zone establishing points of pest detection.

Phase 3:

Surveillance of an intensive nature, to support control and containment activities around points of pest detection.

Phase 4:

Surveillance of contact premises. A contact premise is a property containing susceptible host plants, which are known to have been in direct or indirect contact with an infested premises or infected plants. Contact premises may be determined through tracking movement of materials from the property that may provide a viable pathway for spread of the pest. Pathways to be considered are:

- Items of equipment and machinery which have been shared between properties including bins, containers, irrigation lines, vehicles and equipment;
- The producer and retailer of infected material if this is suspected to be the source of the outbreak;
- Labour and other personnel that have moved from infected, contact and suspect premises to unaffected properties (other growers, tradesmen, visitors, salesmen, crop scouts, harvesters and possibly beekeepers);
- Movement of plant material and soil from controlled and restricted areas; and
- Storm and rain events and the direction of prevailing winds that result in air-borne dispersal of the pest during these weather events.

Phase 5:

Surveillance of nurseries, gardens and public land where plants known to be hosts of May beetles are being grown.

Phase 6:

Agreed area freedom maintenance, post control and containment.

3.5.3 Post-eradication surveillance

Specific methods to confirm eradication of *Phyllophaga* spp. may include:

- Placement of light traps and/or pheromone traps at the site of infection. Traps should be located in areas near host plants, and should be checked for *Phyllophaga* spp. adults at least every 2 weeks from late October through January.

- Monitoring of sentinel plants at the site of infection. Susceptible crops or grassy areas should be sampled in late summer and autumn. The top 15cm of soil in a 50 x 50cm area should be checked from at least 30 sites occurring within 40m of adult food sources (usually deciduous trees).
- Surveys for *Phyllophaga* spp. to be undertaken for a minimum of 3 years after eradication has been achieved as some species require 3-5 years to complete their life cycle. This generation time is longer for species living at higher latitudes than those detected at more tropical locations. Larvae can be detected in the summer and autumn throughout their life cycle.

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5 Appendices

Appendix 1. Standard diagnostic protocols

For a range of specifically designed procedures for the emergency response to a pest incursion refer to Plant Health Australia's PLANTPLAN, Appendices 2 and 3.

Appendix 2. Experts, resources and facilities

The following table lists the experts who can be contacted for professional diagnostics and advisory services in the case of an incursion.

Expert	State	Details
Greg Baker	SA	SARDI (see below)
Dr Mali Malipatil	VIC	DPI Victoria Knoxfield Centre (see below)
Dr Murray Fletcher	NSW	NSW DPI (see below)
Dr Peter Allsopp	QLD	BSES Ltd 50 Meiers Road, Indooroopilly PO Box 86, Indooroopilly QLD 4068 Ph: (07) 3331 3316 email: pallsopp@bses.org.au
Dr Liza Miller	NSW	NSW Department of Environment & Conservation PO Box A290, Sydney South, NSW 1232 Ph: (02) 9995 5690 email: liza.miller@environment.nsw.gov.au
Dr John Rogers	QLD	Research Connections and Consulting PO Box 350, Toowong QLD 4066 Ph: (07) 3720 9065 Fax: (07) 3720 9065
Dr Eric Mathews (semi-retired)	SA	South Australian Museum

		North Terrace, Adelaide, SA 5000 Ph: (08) 8207 7506 Fax: (08) 82077430 email: matthews.eric@saugov.sa.gov.au
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The following table lists the facilities available for diagnostic services in Australia.

Facility	State	Details
DPI Victoria Knoxfield Centre	Vic	621 Burwood Highway Knoxfield VIC 3684 Ph: (03) 9210 9222; Fax: (03) 9800 3521
DPI Victoria Horsham Centre	Vic	Natimuk Rd Horsham VIC 3400 Ph: (03) 5362 2111; Fax: (03) 5362 2187
DPI New South Wales Elizabeth Macarthur Agricultural Institute	NSW	Woodbridge Road Menangle NSW 2568 PMB 8 Camden NSW 2570 Ph: (02) 4640 6327; Fax: (02) 4640 6428
DPI New South Wales Tamworth Agricultural Institute	NSW	4 Marsden Park Road Calala NSW 2340 Ph: (02) 6763 1100; Fax: (02) 6763 1222
DPI New South Wales Wagga Wagga Agricultural Institute	NSW	PMB Wagga Wagga NSW 2650 Ph: (02) 6938 1999; Fax: (02) 6938 1809
SARDI Plant Research Centre - Waite Main Building, Waite Research Precinct	SA	Hartley Grove Urrbrae 5064 South Australia Ph: (08) 8303 9400; Fax: (08) 8303 9403
Grow Help Australia	QLD	Entomology Building 80 Meiers Road Indooroopilly QLD 4068 Ph: (07) 3896 9668; Fax: (07) 3896 9446
Department of Agriculture and Food, Western Australia (AGWEST) Plant Laboratories	WA	3 Baron-Hay Court South Perth WA 6151 Ph: (08) 9368 3721; Fax: (08) 9474 2658

Appendix 3. Communications strategy

A general Communications Strategy is provided in PLANTPLAN

Appendix 4. Market access impacts

Within the AQIS PHYTO database, Pakistan has a range of restrictions for seed / grain consignments to be inspected for pests / weed seed classified as Exotic to Sorghum including *Phyllophaga* spp. Latest information can be found within PHYTO, using an Advanced search “Search all text” for *Phyllophaga* (August 2008).