Biological Control of African Black Beetle *(Heteronychus arator)* in turf using Entomopathogenic Nematodes.

Victorian Golf Association

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Abstract

The larval stage of African Black Beetle *(Heteronychus arator)* is a damaging Scarab pest of turf areas, particularly golf fairways. The importance and frequency of the pest appears to be on the rise in Victoria and has resulted in an increase in the use of insecticides on fairways over the past four years. Previous field work has demonstrated that effective biological control can be achieved using the Entomopathogenic Nematode (EN) *Heterorhabditis* spp. on late larval stages of the pest, but replicated data confirming rates had not been done until now. This trial confirms excellent efficacy (100% control) of the EN species on African Black Beetle larvae, and recommends a rate of 30 - 40 tubs/ha (150,000 - 200,000 nematodes per square metre) for rapid control of third instar larvae.

Introduction

The Victorian Golf Association Turf Research and Advisory Board undertakes research projects of potential benefit to golf clubs and golfers in Victoria. Trial work in the summer of 1999/2000 demonstrated excellent control of Argentine Stem Weevil using Entomopathogenic Nematodes (ENs), which has resulted in widespread and successful adoption of this biological control strategy by clubs. The focus of the trial work for the summer of 2000/2001 was on another major turf pest, African Black Beetle.

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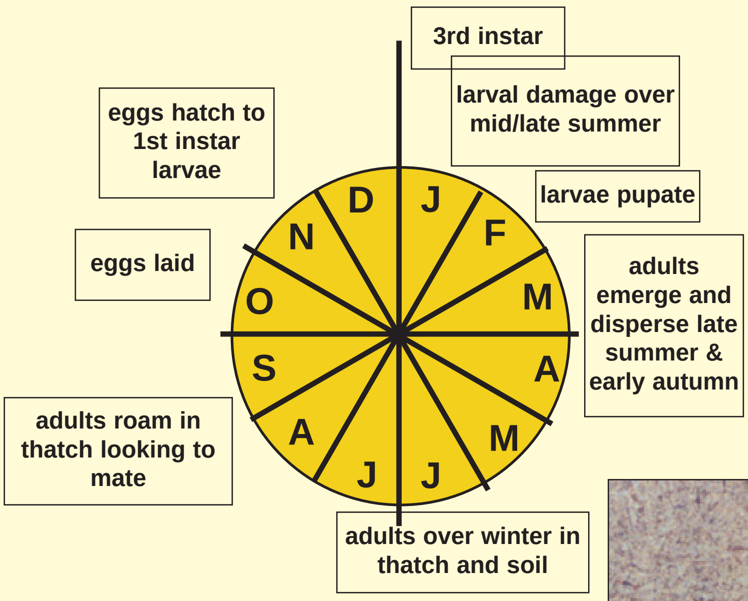
Biology of African Black Beetle

We are fortunate that the biology of African Black Beetle has recently been intensively studied by Dr. John Matthiessen, Principal Research Scientist with CSIRO Entomology, Perth. This explanation of the biology and life cycle of the pest is largely the result of his research. The reference section at the end of this report lists several papers by this author.

African Black Beetle *(Heteronychus arator)* is an introduced pest from southern Africa. Like most introduced pests, it has left its natural predators and pathogens behind and has become a major pest in its new home. It has been a pest of Australian horticulture, forestry and turf since the early 1900s. It is currently widely distributed throughout coastal mainland Australia as far north as Brisbane, down south to Melbourne, as well as coastal South and Western Australia. It is also a pest on the north island of New Zealand. Computer projections based on the climatic conditions that would suit African Black Beetle indicate a potential distribution from far north Queensland right down to southern Tasmania, and it does appear to be spreading. Certainly in Melbourne anecdotal evidence suggests increasing damage to fairways from this pest over the past four years or so.

It follows an annual life cycle, with one generation per year as illustrated below:



In summary the life cycle is as follows. Eggs are laid in October or so, and hatch in November to the first instar larvae. These larvae develop through the second instar and to third instar stage by late January. The third instar larvae are around 12-15mm long, have a tan-yellow head, and the characteristic curl shape, dark rear end and six legs of the scarab group (see photo).

Like all insects with a complete metamorphic life cycle the larva has the job of eating as much as possible, gaining fat to see it through the pupal and adult cycles. The larvae eat plant roots, leaving the turf weak, easily pulled out and prone to summer drought stress. Serious infestations with a density over 100 larvae per square metre can cause this direct turf damage, but even at lower levels of infestation foraging birds can cause more damage than the grub itself. In some cases foraging magpies and crows leave the fairway looking like a ploughed paddock.

The adult beetle can feed in a minor way, but it is the larvae, particularly the third instar larvae, that do the real damage. After the third instar stage the larvae tunnel deeper to pupate (February), and adults emerge through the February to March period. The emerging adults appear to go into a dispersal flight immediately on emergence. The evidence for this is the large number of adults caught in light traps (which only catch flying beetles) at this time, and the low numbers of beetles caught in pitfall traps (which are set into the ground, and only catch walking beetles). This indicates the emerging adults don't walk around on the ground much, but launch straight into their dispersal flight. It is not known how far these flights go, and whether they are migrations or simply dispersals to new areas relatively close by. The flying adults are attracted by lights, but it is not known what other conditions (eg: turf stress, soil fertility, turf species) interact to attract adults to land at a particular spot. Their landing could be completely random, which would result in a fairly even re-distribution of the pest numbers each year.

On landing from their dispersal flight the adult beetles burrow into the thatch and soil where they continue feeding in a minor way and overwinter in a protected site. During this overwintering period the main population develops sexual maturity. With the onset of warmer temperatures in September and October the beetles emerge from the soil to roam on foot in the thatch and grass layer, searching for a mate. They do this roaming on the ground, the evidence being that in spring the light traps (which catch flying beetles) catch almost none, but pitfall traps in the ground catch many adults. At this stage (September) the adult beetles are very susceptible to 'adulticide' insecticide applications (see later).

Biology of African Black Beetle

Once mating has occurred the impregnated female can carry the male's sperm until she is ready to fertilize and lay the eggs. Eggs are laid in the soil, just under the thatch layer. Most egg laying seems to start in late September and be concluded by late October.

The females produce up to 20 eggs (more likely around 12), and the absence of natural predators and pathogens ensures that almost all of these will hatch successfully to larvae. Very wet springs can reduce larval numbers by drowning them. Dry springs (typical of the recent El Nino years) favour the development of damaging numbers. After egg laying the male and female adults die, and the new egg hatch in October-November starts the next generation.

Couch grass is probably the preferred host species, but African Black Beetles can be found in kikuyu and cool season turfs as well. Many clubs, or fairway areas within a club, have a history of consistent re-infestation with Black Beetles and their appearance each summer is somewhat predictable.

Chemical Control Options

The traditional 'larvicide' option has been to monitor larval numbers in the soil into the summer period, and apply an insecticide if these numbers look to be high, or if bird damage is starting. There are a number of problems with this approach:

i) much of the insecticide is bound up in the thatch and top 25mm or so of soil, so only a reduced concentration may reach the grubs in the top 75mm or so of soil. Sometimes no insecticide at all might reach the grubs.

ii) Given the reduced amount reaching the grub, and the large size of the grub, only a high toxicity soil insecticide will do the job. This has usually required insecticides like the organophosphates isazaphos (Oftanol), fenamiphos (Nemacur) or azinphos (Gusathion), all with long persistence and high toxicity. More recently the nicotinyl-derivative imidacloprid (Merit®) has been successful, with good efficacy in the soil at a much reduced level of mammalian toxicity.

iii) These insecticides are hazardous to off-target organisms, such as humans, birds, fish, and beneficial soil invertebrates.

A new approach has come from John Mattheissen's research in Perth. He has shown that an 'adulticide' application of insecticide to the turf during the spring (September) 'roaming' stage of the pest will effectively kill adults before they have a chance to lay eggs into the site. If you spray too early (eg: August), the adults may still be below the thatch layer and not killed. If you spray too late (eg: after mid-October), the adults may already have laid their eggs. Pitfall traps are an excellent way to monitor this 'roaming' phase.

Mattheissen's research has demonstrated near 100% control of the pest using the 'adulticide' approach with various conventional insecticides.

Biological Control Options

The fungus *Metarhizium bassiana* (in Biogreen) may or may not work on African Black Beetle. More research is warranted, but currently Biogreen is only claiming effectiveness on Red Headed Cockchafer.

The Americans are using strains of *Bacillus thuringiensis* for scarab grub control, but again there is no evidence the BT strains available in Australia will work on African Black Beetle.

The main focus in Australian biological control work with turf pests has been on Entomopathogenic Nematodes.

Entomopathogenic Nematodes

Nematodes are tiny worm-like organisms, most species being around one or two millimetres in length. They are just visible to the naked eye if you know what you are looking for. The nematode group is very diverse, and includes species that attack humans, animals (including insects) and plants. There are even nematodes that attack and kill other nematodes, and these have exciting potential to provide biological control of turf nematode problems in the future.

The insect killing (entomo = insect, pathogenic = killing) nematode species used in this trial *(Heterorhabditis spp.)* are beneficial in that they only feed off insect pests. They are not able to switch to feeding off the turfgrass, and can only feed on their insect host. They have no mammalian hazard at all.

Once applied to the soil, the nematodes locate their insect host by detecting movement and following CO_2 emissions. They enter the pest larva via openings such as the mouth, anus or breathing spiracles, or hack their way directly through weak spots in the hosts outer covering.

Once inside the larva they release a bacteria that multiplies up on the insect tissue, quickly killing it. The nematode then feeds off the bacteria, and starts producing many thousands of infective juvenile offspring. When the host insect cadaver finally disintegrates, these infective juveniles then move into the soil to locate a new host, and start the process over again.

Dr. Robin Bedding, of CSIRO Entomology Canberra, has been involved in research on Entomopathogenic Nematodes since the 1960's. This research has identified

Entomopathogenic Nematodes cont....

the most pathogenic EN species for various insect pests, and then developed methods to breed high numbers of the EN in an artificial environment, and finally to induce the EN population to enter a dormant state to allow a reasonable shelf life of the finished product. The end result of his work is a catalogue of practical EN products for a wide range of biological control applications including tree borers, termites, fruit moths, weevils and scarab insect pests. The products contain many millions of ENs in an easily purchased and stored package. In turf situations the EN products can be applied easily through boom spray equipment (filters removed). The ENs must be applied late in the day, as they are sensitive to uv light. The product must also be generously watered in, so application to non-irrigated sites is not advised.

In 1998 David Nickson (then Golf Course Superintendent at Peninsula Country Golf Club, near Frankston) contacted Dr. Bedding and began trialing ENs on Black Beetles, with remarkable success (Bedding and Nickson, 1999). This breakthrough has since led to the use of ENs for a wide range of turf pests, including various Scarab species, Argentine Stem Weevils, Billbugs and even the cutworm and armyworm group.

In 1999 the CSIRO signed a commercialisation agreement with a newly formed company, Ecogrow, to manufacture EN products using the CSIRO patented processes. Ecogrow has established a factory in Canberra for the large scale multiplication and processing of the EN products to serve the Australian market and an emerging export market.

Trial Work: 2001

ENs are now used routinely for the control of African Black Beetle, but there is always a need to conduct scientific trials to fine tune the rates of EN application, and to collect credible data to demonstrate the efficacy of the product to the international turf industry. The purpose of this trial was to generate replicated data on the efficacy of African Black Beetle control.

A suitable site for the trial work became available at Betula Park, a sportsfield managed by the City of Casey. By late January the park was suffering severe Black Beetle damage, both from direct feeding of the insect and from foraging birds. The main area of the field was treated with ENs in early January, and an adjacent area of untreated turf was selected for the trial.

Three replicate plots of four rates of *Heterorhabditis spp.* (Ecogrow product ‘Turf 2’) were sprayed using a 12 volt pump and hose plot sprayer applying a volume of 1 litre per square metre. A standard, label rate of the insecticide Merit was also applied for comparison. Merit is best used as an adulticide or early larvacide, and is not recommended so late in the season on third instar grubs, so its performance should be viewed with that in mind. A set of replicate plots were left untreated (the ‘control’ plots).

The treatments were applied on the evening of January 11th. All plots were well irrigated (around 12mm of irrigation) following treatment, and periodically irrigated over the next three days to assist nematode penetration into the soil. The treatments are summarised below:

Treatment	
Control	No treatment
Merit	Label rate of 2.5 l/ha
EN:10	10 tubs/ha (50,000 ENs per square metre)
EN:20	20 tubs/ha (100,000 ENs/m^2)
EN:30	30 tubs/ha (150,000 ENs/m^2)
EN:40	40 tubs/ha (200,000 ENs/m^2)

The plots were assessed at 7 days after treatment (7 DAT), 14 DAT and 21 DAT. Squares of turf 0.29m x 0.34m were cut to a depth of 0.1 m for counting.

For the first two assessments it was possible to find and count recently killed grubs, allowing a % Kill determination. By the third count, however, the EN-killed grubs had disintegrated and couldn’t be consistently found, so only live grub numbers were analysed.

Results

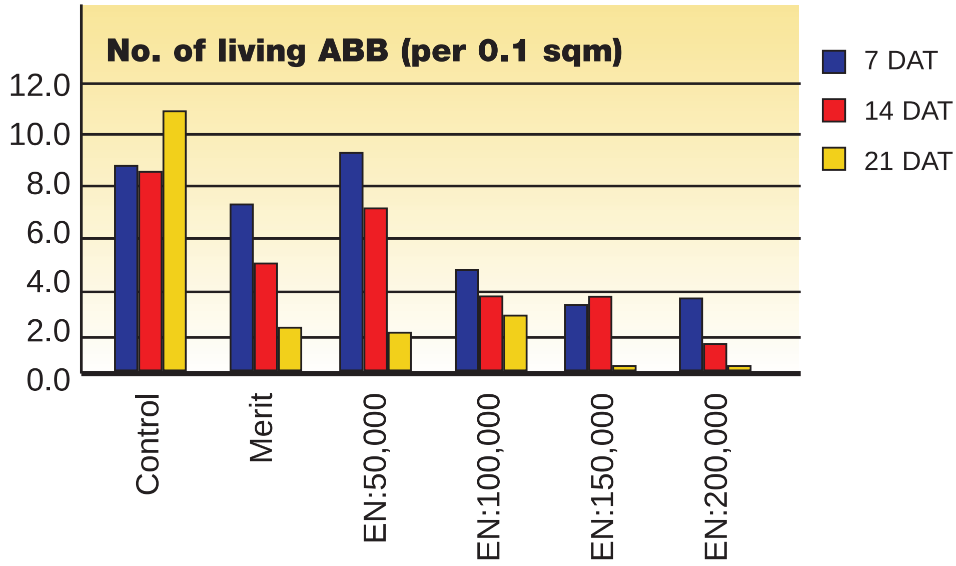
Table 1 summarises the data from the trial. Even at the late stage of application Merit still provided significant control of the larval numbers. The higher EN rates of 30 and 40 tubs/ha (150,000 and 200,000 ENs per square metre) provided at or near total control of the larvae by 21 days after treatment.

Table 1: Summary of assessments for 7, 14 and 21 days after treatment

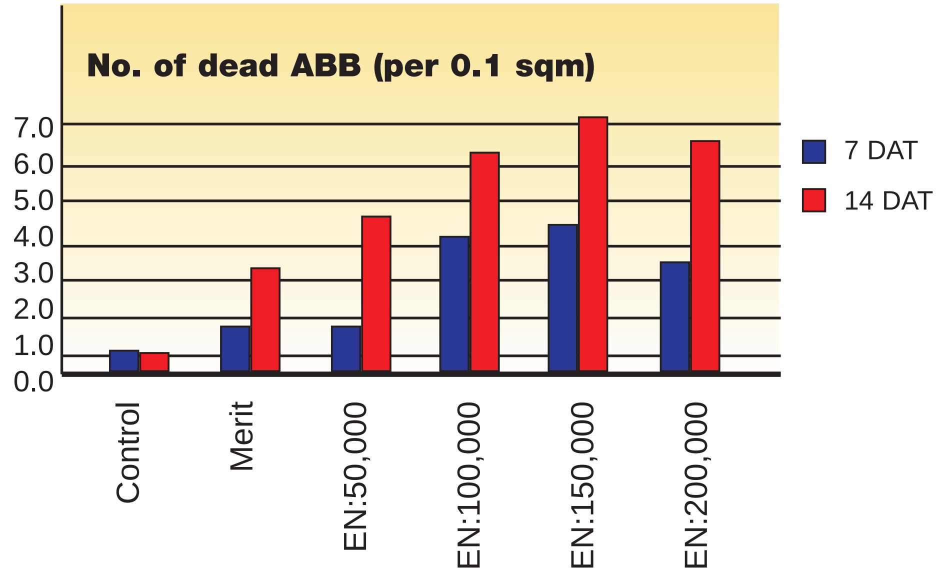
Treatment	7 days after treatment			14 days after treatment			21 DAT
	No. live	No. dead	% kill	No. live	No. dead	% kill	No. live
Control	8.3	0.0	0.0	8.0	0.7	6.7	10.3
Merit	6.7	1.3	23.7	4.3	3.0	41.1	2.0
EN:10	8.7	1.3	23.7	6.7	4.3	41.7	1.7
EN:20	4.0	3.7	44.0	3.0	6.0	64.8	2.3
EN:30	2.7	4.0	61.7	3.0	7.0	79.7	0.0
EN:40	3.0	3.0	50.0	1.3	6.3	87.9	0.0
LSD (95%)	6.5	3.6	34.0	4.8	6.5	35.8	4.0

Graphs 1, 2 and 3 illustrate some of the data from Table 1.

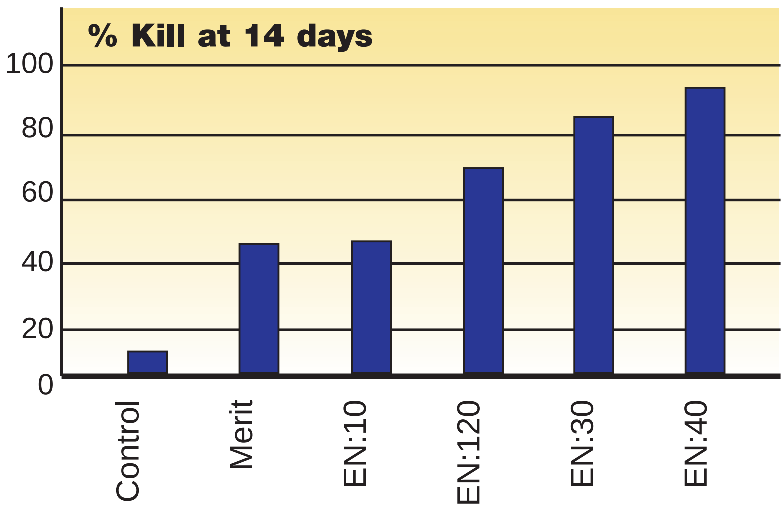
Graph 1:
Number of living grubs at 7, 14 and 21 days after treatment



Graph 2:
Counts of dead larvae found at 7 and 14 days after treatment. Even the control plots had a few dead grubs because of a low, background presence of two other biological pathogens, Milky Disease (*Bacillus spp.*) and *Cordyceps gunnii.*



Graph 3:
Because larvae killed by the ENs were able to be found and counted at 7 and 14 days after treatment, it was possible to relate the number of living and dead grubs to estimate the % Kill, as shown.



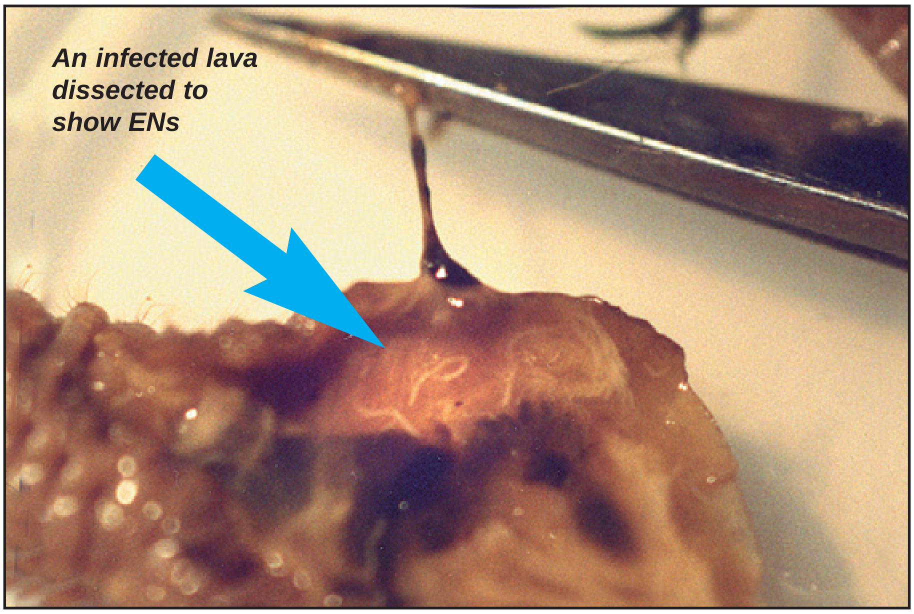
Summary of Results

A rate of 30 - 40 tubs/ha (150,000 - 200,000 ENs per square metre) of the EN product is probably the optimum rate to use for existing third instar African Black Beetle infestations. If applied correctly the control achieved should be close to 100%.

Third instar larvae of African Black Beetle. The one on the right is healthy, the others have been infected with *Heterorhabditis*.

Other points regarding the use of ENs for Black Beetle control

i) Insecticides are at their most effective when using the ‘adulticide’ approach, aiming to kill roaming adults in September before they lay the seasons eggs. Unfortunately this approach requires untargetted, broadacre spraying because you can’t delineate where the insects will be concentrated. Leaving the insecticide application until later (the conventional ‘larvicide’ approach) is not highly effective as the bigger grubs are hard to kill, and it is difficult to get a killing concentration of insecticide into the soil.



An infected lava dissected to show ENs

ii) In all trial work to date, the ENs work extremely well on large larvae, so spraying can be left until late in the summer. The bigger the grub, the easier it is for the ENs to find, and the more effective the control.

iii) ENs work extremely well on big larval populations. The more dense the grub population, the greater the chance of ENs finding their host, and the more chance of a second wave of parasitism (where the thousands of infective juveniles produced in the cadavers of grubs killed by the initial application move back into the soil, looking for further hosts).

iv) Birds target grub populations that are big and dense, so bird feeding gives you the ability to better delineate the problem area and limit the area sprayed, so that EN control can be more cost effective. Many clubs are finding their insect-control costs actually being reduced using ENs, as the area sprayed is reduced by better targetting.

v) ENs kill the larvae so quickly that bird damage ceases within three to five days. Birds hunt for the living grubs by honing in on the noise and vibrations of grub movement. But when the grubs are killed the birds don’t forage randomly looking for grubs, they will go and look somewhere else.

vi) With an insecticide application it is inevitable that birds will end up eating sprayed grubs. With ENs there is no such off-target hazard.

Concluding remarks

The VGA Turf Research and Advisory Board is keen to pursue, through trial work, the concept of the ‘Insecticide-Free Golf Course’. Such a concept will have benefits to golfers, turf industry workers and the ecology of the golf course habitat. The concept is also important in presenting a pro-active attitude to environmental issues to the community at large.

The new EN products have a major part to play in bringing this concept to life, and we will continue our efforts in this area. Our work this year on African Black Beetle, and last summer on Argentine Stem Weevil, has demonstrated excellent and cost effective control of these pests. Any findings and / or recommendations found in this report are based on a set of trials and conditions laid down within the report and should not be taken as decisive or conclusive. It is, however, hoped that this research assists clubs and superintendents to make relevant decisions best suited to their club and conditions.

Acknowledgement

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