Improved Mole Cricket Management Through the Application of an Enhanced Ecological and Behavioral Data Base

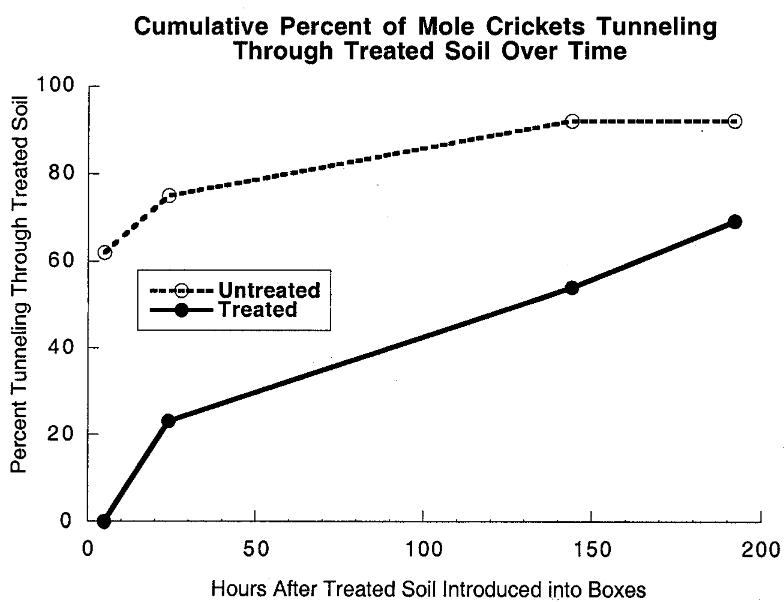
North Carolina State University
Rick L. Brandenburg

Cornell University
Michael G. Villani

Objectives:

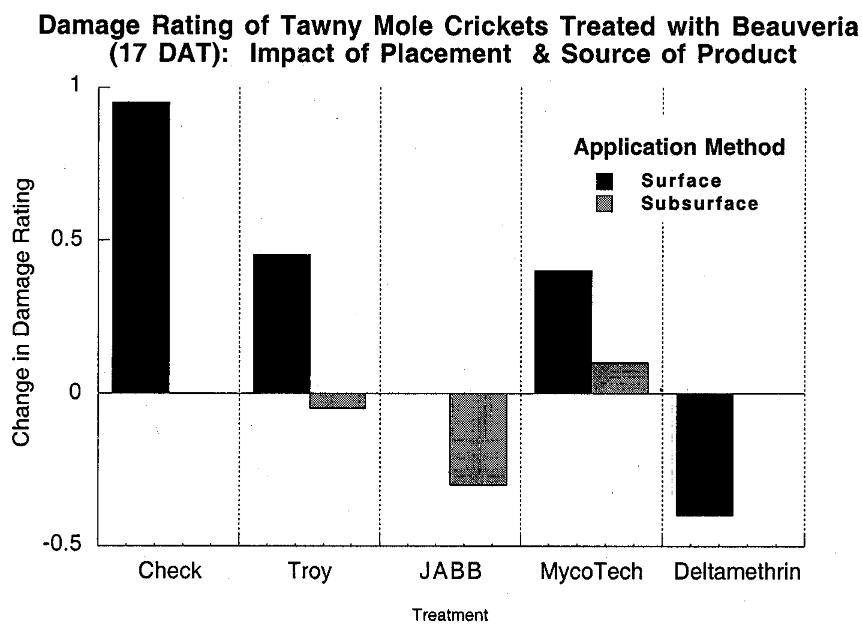
1. Develop an effective integrated pest management program for mole crickets that ultimately reduces total pesticide use through improved implementation of chemical strategies and effective integration of biological and cultural options.
2. Apply the extensive research findings and validation of biological control strategies based upon our new knowledge of mole cricket ecology and behavior.

Laboratory and field studies were initiated to evaluate mole cricket behavior toward entomopathogenic soil fungi and to evaluate the efficacy of subsurface and surface fungal applications. The effect of the entomopathogenic fungi, *Beauveria bassiana* and *Metarhizium anisopliae*, on the behavior of tawny mole crickets (TMC) was tested using two experimental methods. In the first set of experiments, TMC had no choice but to tunnel through a layer of fungal treated sand in order to reach a sod food source. As seen in the figure below, TMC in untreated boxes tended to tunnel to the surface more quickly and in greater numbers than TMC in boxes treated with fungal pathogens. Some TMC started to tunnel into fungal treated sand and then changed direction and tunneled below or away from the treated layer. In similar laboratory investigations, white grubs also avoided soil treated with a fungal pathogen.



In the second set of experiments TMC were given a choice to establish tunnels in clean or *B. bassiana* treated sand. replicates of each treatment. TMC s in buckets of sand half treated with *B. bassiana* and half untreated tunneled exclusively in the untreated sand. In buckets of untreated sand TMC tunneled regardless of side and tunnels were somewhat larger than those in the choice treatment. In buckets of *B. bassiana* treated sand, tunnels were extremely small or nonexistent. In two of the four buckets of treated sand the TMC was found at the interface between the sand and sod.

In 1997 and 1998, two commercial products, Naturalis-T (Troy Biosciences Corp., Phoenix, AZ) and BotaniGard ES (MycoTech Corp., Butte, MT), containing *B. bassiana*, were field tested for control of mixed nymphal populations of the southern mole cricket and the tawny mole cricket. mole cricket damage ratings from surface applied *B. bassiana* treated plots were not significantly different from the untreated control. In 1999, three commercial products containing *B. bassiana*, Naturalis-T (Troy Biosciences Corp., Phoenix, AZ), BotaniGard ES (MycoTech Corp., Butte, MT, and 7695 SCK (JABB, Carolina Inc, Pine Level, NC), were applied to field plots using subsurface injection as well as surface sprays. The change in mole cricket damage ratings between pre and post treatment was compared. As in the graph below, damage ratings were significantly reduced in plots treated with subsurface injections of 7695 SCK (JABB, Carolina Inc, Pine Level, NC) and surface sprays of the insecticide control Deltamethrin. In contrast, mole cricket damage ratings increased or did not change in plots treated with surface applications of *B. bassiana* and in the untreated control.



These findings suggest that placement of fungal pathogens in the soil profile may influence the effectiveness of a product to control mole cricket damage to turf. The avoidance response seen in laboratory experiments may be evidence of an evolutionary adaptation to avoid infected insects and areas of soil with high concentrations of fungal spores. Avoidance behavior may explain the inconsistent results found in the field with high doses and surface applications of fungal pathogens. Subsurface applications of fungal pathogens may lengthen the time a pathogen remains viable compared to pathogen survival after surface application.

Future studies will include: tests of mole cricket behavior toward the carriers contained in fungal formulations, in depth analysis of mole cricket movement in the radiographs (such as calculation of the area of the tunnels to see if the amount of tunneling was different in treated and untreated areas), and a comparison of fungal viability in the soil overtime after surface and subsurface applications.

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Tawny mole crickets (TMC), *Scapteriscus vicinus* Scudder and southern mole cricket (SMC), *S. borellii* cause severe damage to turfgrass in the southeastern United States (Brandenburg 1997). Controlling mole crickets is difficult since these pests live in the soil and are less likely to contact insecticides. Many abiotic and biotic factors such as soil moisture and temperature, weather conditions, and insect developmental stage can cause significant variation in the efficacy of control efforts. Chemical insecticides are frequently used to control mole crickets. However, insecticide application rates for control of these soil dwelling pests are usually much higher than those used for controlling foliar insect pests. Repeated applications during the season are often necessary to achieve acceptable control. In addition, higher insecticide application rates and the proximity of these infested turf areas to residential or chemically sensitive natural habitats has caused increasing concerns about the potentially adverse impacts of insecticide applications on humans and the environment.

The naturally occurring soil fungi *Beauveria bassiana* and *Metarhizium anisopliae* are known to infect many soil arthropods including mole crickets and other turf pests (Sailer 1984, Brandenburg and Villani 1995). Both fungi have been used to control a variety of insect pests; however, published investigations in turfgrass have been limited to white grubs (Heller and Walker 1997). There are no published studies using fungal pathogens for controlling mole crickets.

Preliminary studies with spray applications of *B. bassiana* indicate that reverse rate responses often occur with higher rates providing less control. This may be the result of avoidance behavior associated with higher rates. Mole crickets may detect and avoid formulations containing pathogenic fungi by remaining deep in the soil profile (Villani et al. 1999). This behavior would allow the mole crickets to avoid the fungal pathogen until it becomes inactive and then resume tunneling, causing increased damage.
In a laboratory experiment on mole cricket dispersal, Fowler (1988) found mole crickets treated with *M. anisopliae* were more active and dispersed further than untreated mole crickets. Increased dispersal could result in more damage if mole crickets tunnel to escape a treated area or it could result in less damage if mole crickets disperse and avoid treated areas.

Laboratory and field studies were initiated to evaluate mole cricket behavior toward entomopathogenic soil fungi and to evaluate the efficacy of subsurface and surface fungal applications.

Laboratory Experiments

Late instar TMC used in laboratory experiments were collected at the Meadowlands Golf Course in North Carolina on September 13 and 14, 1999. TMC were flushed out of the turf using soapy water. Garden watering cans were filled at a nearby pond and 2 tablespoons of dish detergent added. The turf was scouted for signs of TMC activity such as small lines of disturbed turf and soapy water was poured over a 2-foot square area. Then the area was closely observed and TMC were collected individually as they emerged. Each TMC was carefully rinsed in fresh pond water to remove any harmful soap residue. Each flush resulted in collection of an average of 5 TMC. This process was repeated until approximately 1,000 TMC were collected. TMC were stored in large coolers filled with moist sand and turfgrass.

The effect of the entomopathogenic fungi, *Beauveria bassiana* and *Metarhizium anisopliae*, on the behavior of tawny mole crickets (TMC) was tested using two experimental methods.

In the first set of experiments, TMC had no choice but to tunnel through a layer of fungal treated sand in order to reach a sod food source. Plexiglass boxes 1.5 x 12 x 15 in (50 x 300 x 380mm) were filled with 9 inches of clean sand at 8% moisture. One late instar TMC was placed in each box and allowed to tunnel for 1 hour then strips of sod were placed on top of the sand. After 4 days, the sod was removed and 2 inches of fungal treated sand was added to the surface of the sand. An equivalent layer of clean sand was added in control treatments.

In tests of *B. bassiana*, 1 ml of BotaniGard ES (MycoTech Corp., Butte, MT) at 2 x 10^{13} spores/ml mixed into 450 g of sand was added to each of 13 boxes, with 13 control boxes. In tests of *M. anisopliae*, the fungus was grown on boiled rice in the lab, sporulating rice was mixed with sand in a ratio of 1: 5 and 8 oz of treated sand was added to each of 10 boxes, with 10 control boxes. Sand mixed with clean boiled rice was added to an additional 10 control boxes.

To observe changes in mole cricket tunneling behavior, X-rays were taken pretreatment, and 5 hours, 24 hours, 6 days, and 8 days post treatment in tests of the *B. bassiana*; formulation; and 2 hours, 3 days, and 6 days in tests of *M. anisopliae* grown on rice. At the end of each test wax castings were made of TMC tunnels to verify that X-rays were accurately depicting actual tunnels (Fig. 1).

In tests of the *B. bassiana* formulation, 5 hours after treatment 0 % of the TMC in treated boxes compared to 62% of TMC in control boxes had tunneled through the treatment layer and returned to the surface sod (Figure 2). After 24 hours, 23% of TMC in treated boxes and 75% of TMC in untreated boxes had tunneled through (Figure 2); after 6 days, 54% of TMC in treated boxes and 92% of TMC in untreated boxes had tunneled through; and after 8 days, 69% of TMC in treated boxes and 92% of TMC in untreated boxes had tunneled through (Figure 3). After 8 days, all TMC were alive. One TMC moulted to an adult during the experiment; interestingly this was the only TMC in the control treatment that did not tunnel to the surface sod. It is important to note that the fungus was tested in a formulation containing carriers that may also have effected TMC behavior.

In tests of *M. anisopliae*, 2 hours after treatment 40 % of the TMC in both treated boxes and untreated boxes had tunneled through the treatment layer and returned to the surface (Figure 4). After 3 and 6 days, 60% of TMC in treated boxes and 80% of TMC in untreated boxes had tunneled through to the surface sod (Figure 4). Some TMC tunneled into the *M. anisopliae* treated sand layer and then changed direction.

In the second set of experiments TMC were given a choice to establish tunnels in clean or *B. bassiana* treated sand. Two buckets of sand were set up using three treatments, 1. all clean sand, 2. half the bucket vertically filled with sand treated with *B. bassiana*, using the same formulation and concentration as in Experiment 1, 3. all *B. bassiana* treated sand.

One TMC was released onto the surface of the sand in each bucket and allowed to tunnel. Once the TMC had disappeared below the surface sod was added. After four days, the sod was removed and wax was poured into any holes found at the sands surface. Wax castings of TMC tunnels were carefully excavated from each bucket and the location of the tunnels in relation to the treatments noted. The test was repeated once for a total of four replicates of each treatment.

TMC s in buckets of sand half treated with *B. bassiana* and half untreated tunneled exclusively in the untreated sand (Figure 5). In buckets of untreated sand TMC tunneled regardless of side and tunnels were somewhat larger than those in the choice treatment (Figure 5). In buckets of *B. bassiana* treated sand, tunnels were extremely small or nonexistent (Figure 5). In two of the four buckets of treated sand the TMC was found at the interface between the sand and sod.

Field Experiments

In 1997 and 1998, two commercial products, Naturalis-T (Troy Biosciences Corp., Phoenix, AZ) and BotaniGard ES (MycoTech Corp., Butte, MT), containing *B. bassiana*, were field tested for control of mixed nymphal populations of the southern mole cricket and the tawny mole cricket. These products were applied as liquid sprays on the surface of sod that was irrigated pre and post application. A damage rating system was used to determine mole cricket abundance and activity. A PVC frame, 75 cm on each side and divided into 9 equal, square-shaped sections was used. The frame was placed on the ground and, using visual and manual inspection, the number of sections which contain mounds or tunnels was counted. In each square, any activity (whether one or several tunnels) was scored as "1", while squares with no activity were scored as "0". The total score for the 9 squares is recorded. Thus, damage ratings range from 0 (no damage in any of the sections) to 9 (damage in all of the sections) (Cobb and Mack 1989). In 1997 and 1998, mole cricket damage ratings from surface applied *B. bassiana* treated plots were not significantly different from the untreated control.

In 1999, three commercial products containing *B. bassiana*, Naturalis-T (Troy Biosciences Corp., Phoenix, AZ), BotaniGard ES (MycoTech Corp., Butte, MT, and 7695 SCK (JABB, Carolina Inc, Pine Level, NC), were applied to field plots using subsurface injection as well as surface sprays. The change in mole cricket damage ratings between pre and post treatment was compared. Damage ratings were significantly reduced in plots treated with subsurface injections of 7695 SCK (JABB, Carolina Inc, Pine Level, NC) and surface sprays of the insecticide control Deltamethrin (Figure 6). In contrast, mole cricket damage ratings increased or did not change in plots treated with surface applications of *B. bassiana* and in the untreated control.

Conclusion

In laboratory experiments, TMC in untreated boxes tended to tunnel to the surface more quickly and in greater numbers than TMC in boxes treated with fungal pathogens. Some TMC started to tunnel into fungal treated sand and then changed direction and tunneled below or away from the treated layer. In similar laboratory investigations, white grubs also avoided soil treated with a fungal pathogen.

In field experiments, subsurface application of *B. bassiana* reduced damage to turf by mole crickets.

These findings suggest that placement of fungal pathogens in the soil profile may influence the effectiveness of a product to control mole cricket damage to turf. The avoidance response seen in laboratory experiments may be evidence of an evolutionary adaptation to avoid infected insects and areas of soil with high concentrations of fungal spores. Avoidance behavior may explain the inconsistent results found in the field with high doses and surface applications of fungal pathogens. Subsurface applications of fungal pathogens may lengthen the time a pathogen remains viable compared to pathogen survival after surface application.

Future studies will include: tests of mole cricket behavior toward the carriers contained in fungal formulations, in depth analysis of mole cricket movement in the radiographs (such as calculation of the area of the tunnels to see if the amount of tunneling was different in treated and untreated areas), and a comparison of fungal viability in the soil overtime after surface and subsurface applications.

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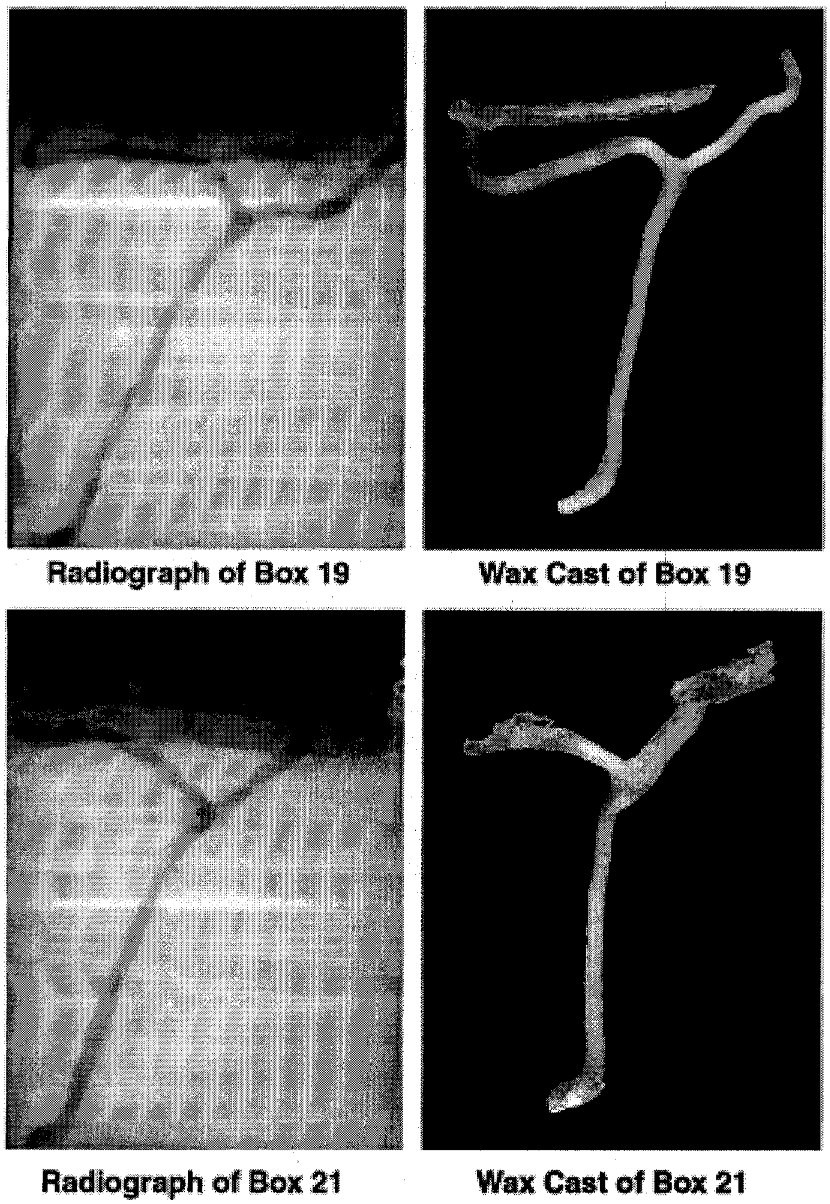

Fig. 1. Comparison of x-ray radiographs and wax castings of tawny mole cricket tunnels in experimental boxes.

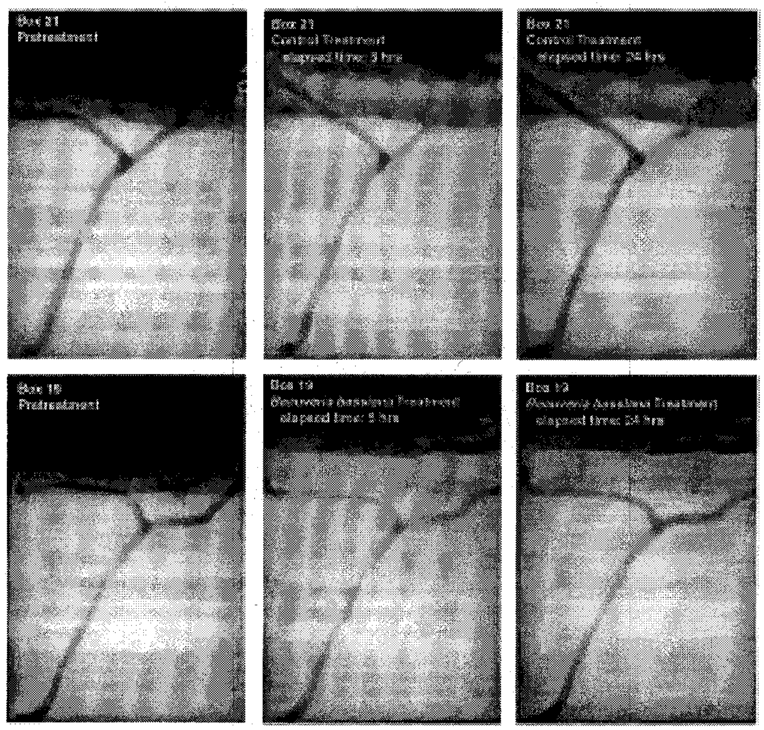

Fig. 2. Radiograph of tawny mole cricket tunnels pretreatment, 5, and 24 hours after addition of sand layer, control and *Beauveria bassiana*.

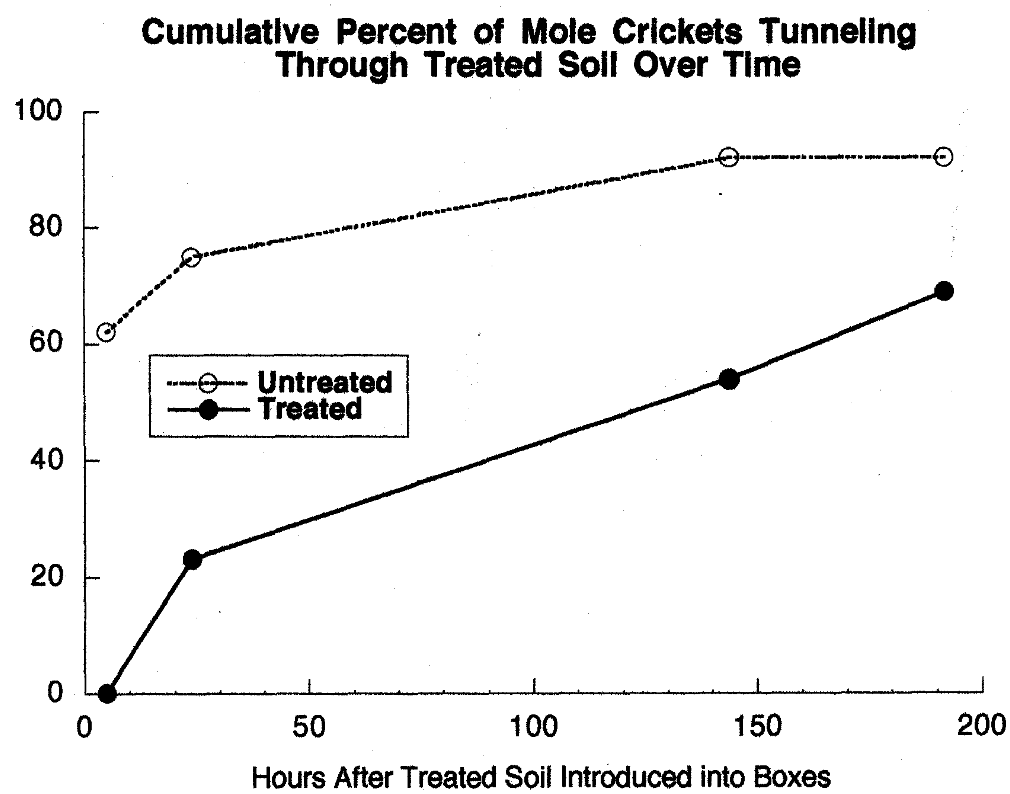

Figure 3. Percentage of tawny mole crickets tunneling to sod surface, 5 hours, 24 hours, 6 days and 8 days after addition of sand layer: control and *Beauveria bassiana*.

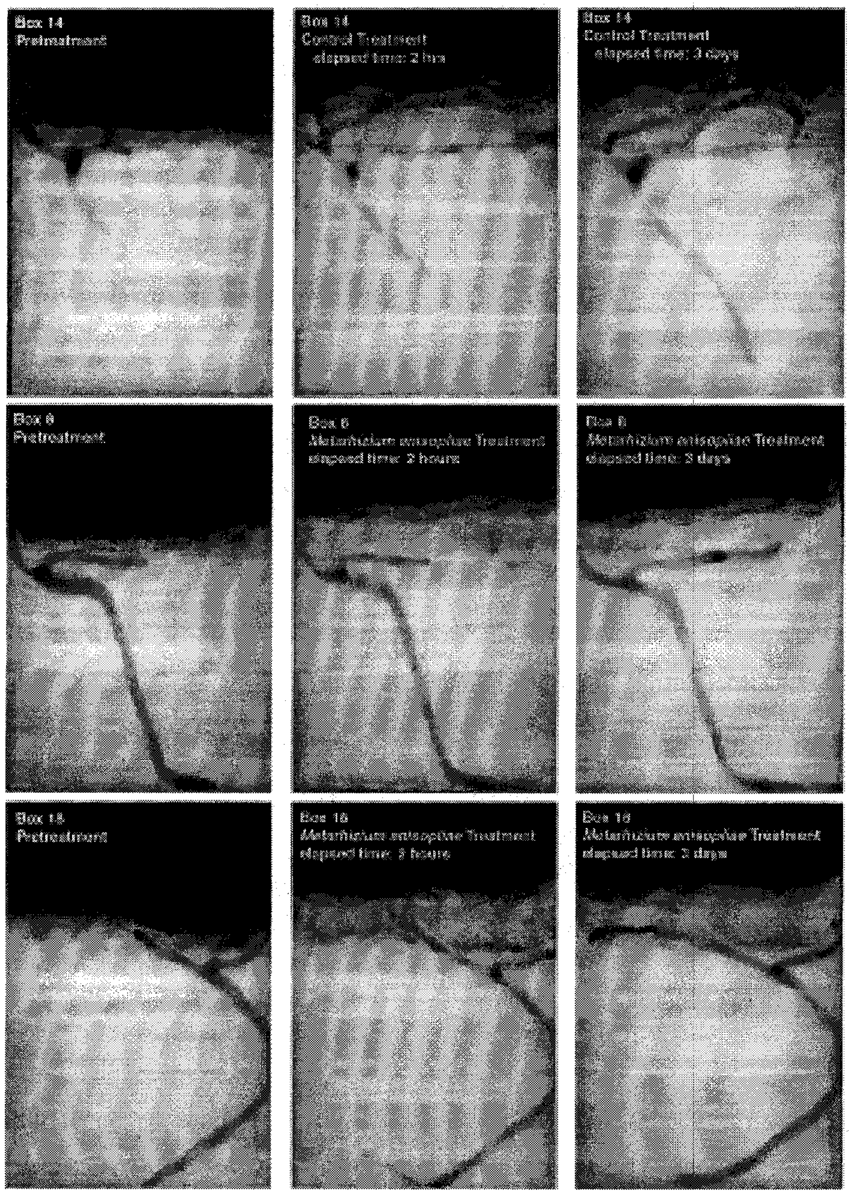

Fig. 4. Radiograph of tawny mole cricket tunnels pretreatment, 2 hours, and 3 days after addition of sand layer, control and *Metarhizium anisopliae*.

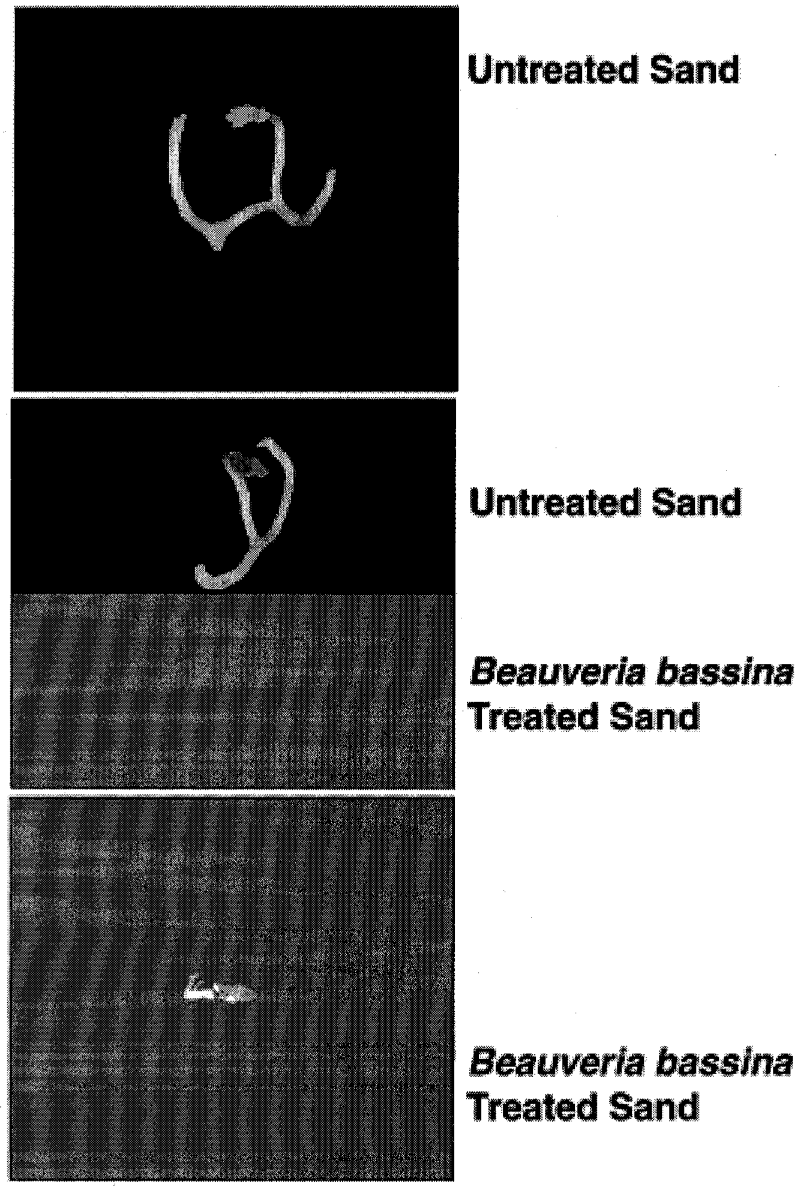

Fig. 5. Wax castings of tawny mole cricket tunnels in buckets of 100% untreated, 50% untreated and 50% *Beauveria bassiana,* and 100% *Beauveria bassiana.*

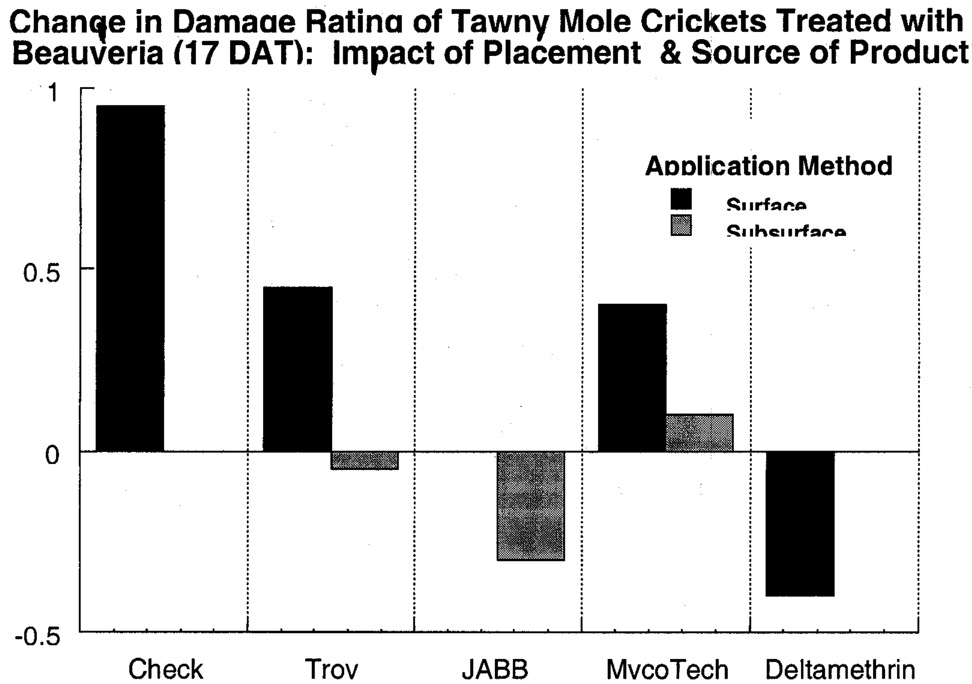

Figure 6. Impact of placement and source of product on change in tawny mole cricket damage ratings 17 days after treatment with *Beauveria bassiana*