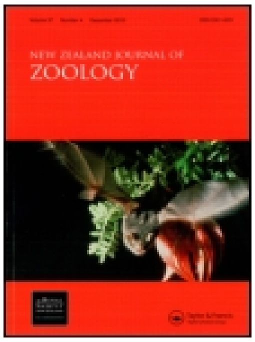

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Poisoning of honey bees (*Apis mellifera*) by sodium fluoroacetate (1080) in baits

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Abstract The behaviour of honey bees feeding on sodium fluoroacetate-jam baits, which are used for opossum control, was investigated to determine the reasons for reported honey bee kills. Honey bees were shown to feed readily on 1080-jam baits when they were presented outside their hives. There were no debilitating effects for up to 2 h after feeding on the baits, which allowed them to make up to four foraging trips to the baits and recruit additional foragers.

Black strap molasses was shown to have a repellent effect on honey bees when mixed with the jam baits. Foragers were able to detect differences in concentration of as little as 5%. Twenty percent molasses was found to repel inexperienced foragers strongly; however, they could be trained to accept higher concentrations. Two percent oxalic acid (a component of molasses) was found to repel honey bees when added to 2M sugar syrup or jam baits. Molasses-jam baits and jam baits appeared to be equally attractive to opossums when tested in the field.

These results suggest that molasses or oxalic acid may could be incorporated with 1080-jam baits to prevent honey bees feeding on them.

Keywords honey bees; poisoning; sodium fluoroacetate; repellents; molasses; oxalic acid

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INTRODUCTION

Sodium fluoroacetate (1080) is used in New Zealand to control opossums (*Trichosurus vulpecula*). It is added to either jam or carrot baits. The jam baits contain 1080 at a concentration of 0.05%, 0.08%, or 0.15% w.w. and are dyed green (Permicol Green 20–6794 dye) to protect birds. Cinnamon is added to mask the flavour of the 1080 poison (Morgan 1985).

After closely monitoring poisoning programs over 6 years, McIntosh et al. (1964) were unable to find evidence of mass mortality of honey bees (*Apis mellifera*) and concluded that jam baits did not endanger honey bees or effect honey. However, large bee kills have been reported recently in areas where opossum poisoning programmes have been conducted. Of four samples of dead honey bees tested, three have been found to contain 1080 (3.1, 3.8, and 10 mg/kg bees, unpublished test results).

The high bee mortalities reported recently may be caused by the poison jam formulation having been changed since the early trials (McIntosh et al. 1964). The raspberry jam has been replaced with apple, the green dye is now a legal requirement, the wide divergences in toxicity of the bait have been eliminated, and cinnamon has been added along with 800 ppm potassium sorbate anti-fungal preservative (Logan pers. comm. 1987).

The LD_{50} for technical grade sodium fluoroacetate in 0.02 ml of sucrose solution fed to honey bees is 0.8 μg (Palmer-Jones 1957). However, those tests bear little relationship to the actual toxicity of 1080 to foraging honey bees because the bees were starved and then permitted to consume a full dose of the 1080-sucrose solution. Those that regurgitated any of the solution were discarded. Under field conditions, a foraging honey bee collecting the jam baits would not be starved first and therefore would not imbibe as much 1080 as a starved bee. A starved bee would presumably also take more syrup from its crop into its stomach than a bee foraging on 1080-jam baits. Also, foragers would regurgitate most of their load when returning to their hive and would only consume small amounts of any 1080-jam they collected. It is

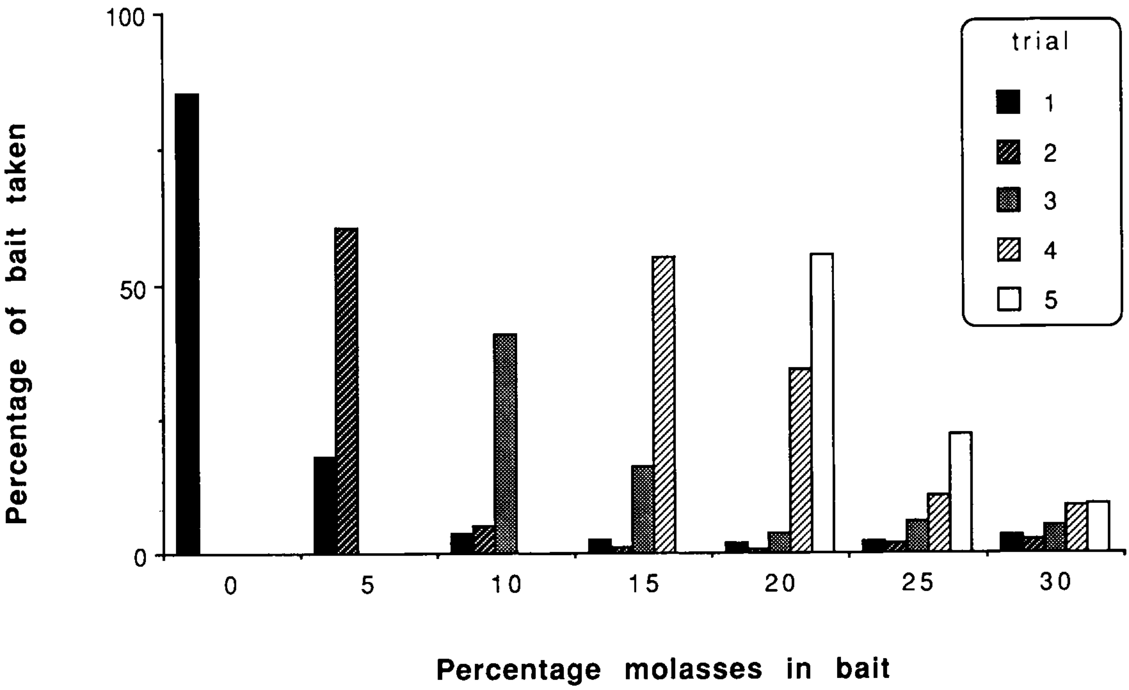

Fig. 1 Percentage of molasses-jam baits taken, over 7 h, with increasing molasses concentrations (all concentrations at the same feeding station). The lowest concentration was removed for each consecutive trial.

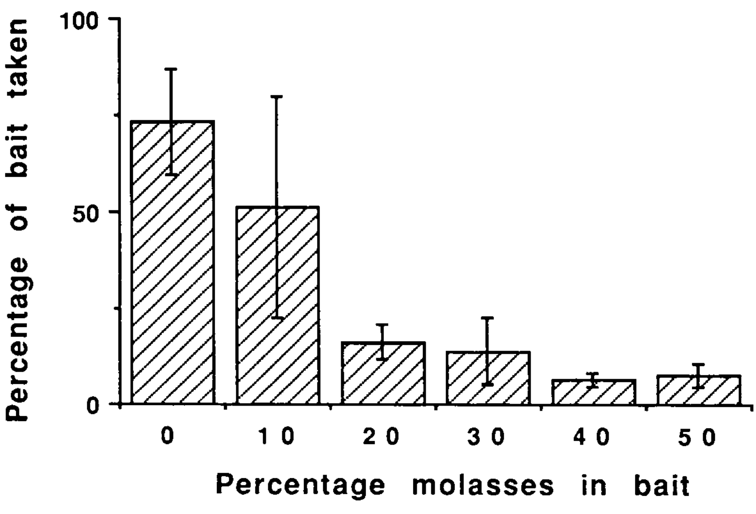

Fig. 2 Percentage of molasses-jam baits taken, over 7 h, with increasing molasses concentration (only one concentration at each feeding station). The vertical lines are standard errors of 9 replicates.

thus possible that they could collect 1080-jam and pass it to house bees without receiving a lethal dose.

At present, operators are instructed not to lay baits closer than 400 m from apiary sites to reduce the possibility of honey bees feeding on the baits. The choice of a 400 m limit does not however appear to be based on any scientific evidence. The 400 m limit was devised when all poisoning was carried out during June and July. Poisoning programmes are

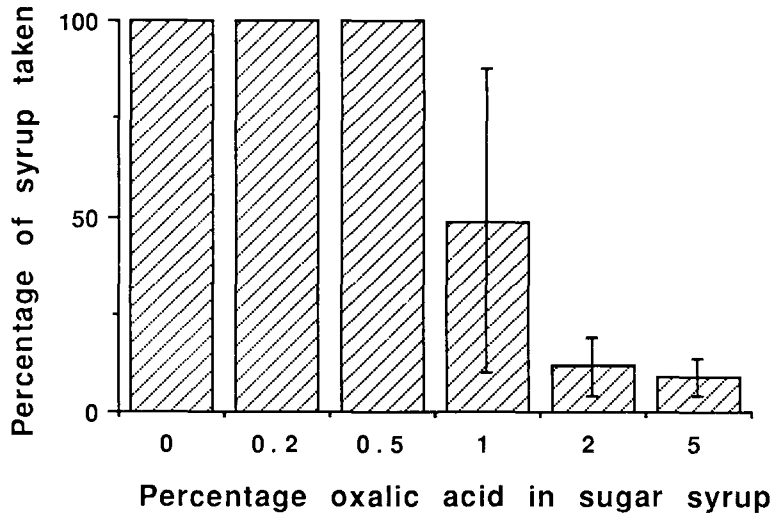

Fig. 3 Percentage of oxalic acid-sugar syrup taken, over 1 h, with increasing oxalic acid concentration (all concentrations at the same feeding station). The vertical lines are standard errors of 6 replicates.

now also carried out in the spring and early autumn when honey bees forage more actively. Registered beekeepers are usually notified of any poisoning programmes and are asked to remove their hives while the poisoning is carried out.

The aim of this investigation is to describe the behaviour of honey bees presented with 1080-jam baits and to determine whether molasses or oxalic acid could be used to repel honey bees from baits. Uematsu et al. 1985 reported that honey bees find molasses to be relatively unattractive. Honey solutions containing 0–10% molasses were accepted by foraging honey bees whereas those containing higher concentrations of molasses were less acceptable.

As molasses is frequently used as stock feed and has been incorporated in opossum baits previously it is likely to be attractive to opossums. Trials conducted with molasses incorporated with pellets have shown that the addition of molasses does not effect the bait's attractiveness to opossums (Morgan 1985; Morgan pers. comm.).

Oxalic acid, along with citric, malic, and glycolic acids make up between 1–5% of molasses (percentage weight) (Meade & Chen 1977). However, there is nothing in the literature to suggest that oxalic acid is repellent to honey bees. The only references to oxalic acid and honey bees is for its use in the control of varroa mites.

MATERIALS AND METHODS

The first trials were to determine if foragers would visit jam baits, and how long foragers survived after consuming 1080 from baits when they have the opportunity to pass most of it to house bees on returning to their hive. This was extended to determine how many foraging trips honey bees can make to baits before they succumb to the 1080.

Further trials were conducted to ascertain if molasses or oxalic acid (a component of molasses) could be used to repel honey bees from jam baits.

Exploitation of jam baits

Trial 1. Ten jam baits were laid around a group of three hives to determine whether honey bees would forage from jam baits. The jam baits were apple based (including the skin and core but excluding the pips) with 35% sugar and 30% water. The baits were approximately 2 m from the colonies. They were then checked every hour to determine the number that were being visited by foraging honey bees.

Trial 2. The survival rate and survival time of honey bees making one foraging trip to a 1080-jam bait was investigated by training honey bees from a two-frame observation hive to feed from a non-toxic jam bait laid about 3 m from the hive. The jam bait was then exchanged for a 1080-jam bait. About 20 foragers were permitted to feed on the 1080-jam bait. They were then marked individually with water colour paints while feeding on the baits. Each forager was only permitted to visit the 1080-jam bait once. The bait was removed when 20 foragers had been marked or when the first marked forager returned for a second trip. The marked foragers were observed each hour inside the observation hive over the next 6 h and again 24 h later. A record was kept of the number of

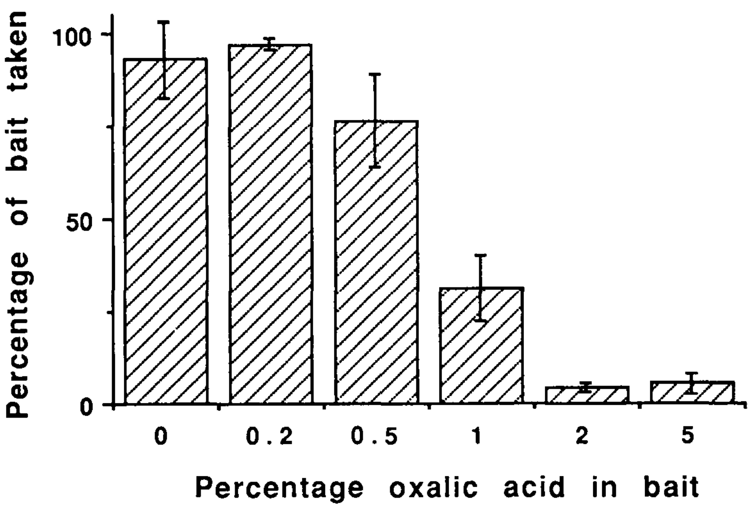

Fig. 4 Percentage of oxalic acid-jam baits taken over 7 h with increasing oxalic acid concentration (only one concentration at each feeding station). The vertical lines are standard errors of 10 replicates.

marked foragers that died over this time. This was repeated four times over several weeks until a total of 79 foragers were tested.

Trial 3. The number of foraging trips that could be made to a 1080-jam bait was determined by training foragers to a jam bait laid 3 m from a hive. The jam bait was then exchanged for a 1080-jam bait. Twenty foragers were permitted to feed from the bait. These foragers were individually marked. A record was kept of the number of return trips each forager made to the bait.

Repellency of blackstrap molasses

Trial 1. Jam baits were made up that contained (W:W) 0, 5, 10, 15, 20, 25, and 30% blackstrap molasses. Honey bees were trained to a feeding station 20 m from their colony. Sugar syrup was placed at the feeding station each morning. When large numbers (>100) of bees were feeding, the syrup was replaced with the jam and molasses-jam baits. The baits (approx. 4 g) were placed in small plastic petri-dishes and weighed. Four replicates of each concentration were arranged randomly at the feeding station at about 0900 h. The baits were removed and weighed between 1600 and 1700 h to determine the amount of the baits consumed.

The first trial also consisted of a set of controls to determine weight loss caused by evaporation. The controls consisted of one bait of each concentration covered by a wire cage to prevent honey bees gaining access. The trial was repeated on five consecutive days. The lowest concentration was removed from each successive trial until only 20, 25, and 30% molasses remained, to determine if foragers could be trained to accept baits with high molasses concentrations.

Trial 2. The attractiveness of molasses-jam baits to inexperienced foragers was tested by establishing five feeding stations in a half circle about 30 m from the hives. Foragers (>100) were trained to accept sugar syrup at each feeding station. The foragers were permitted to collect sugar syrup at the feeding stations on the morning before the trial. When sufficient foragers were visiting the feeding stations the sugar syrup was replaced with one Petri-dish containing the jam pre-bait (control) and four dishes of either 10, 20, 30, 40, or 50% blackstrap molasses-jam. The baits were removed at the end of the day and weighed to determine the amount consumed. The trial was repeated a week later with five dishes of one of the five concentrations and one control at each feeding station. The location of each concentration was different from the previous replicate.

Repellancy of oxalic acid

Trial 1. A large number of foragers (>500) were trained to accept sugar syrup at a feeding station. When the training solution was finished it was replaced with small dishes of 2M sucrose solutions (10 ml) containing different concentrations of oxalic acid (0, 0.2, 0.5, 1, 2, and 5%). Two molar sugar syrup is considerably more attractive to honey bees than the jam baits which have a much lower sugar concentration. There were three dishes of each concentration. The dishes were arranged randomly at the feeding station. The dishes were weighed after 1 h to determine the amount of the solutions consumed. The trial was repeated later on the same day.

Trial 2. The repellancy of the baits to inexperienced foragers was tested in the same manner as with the black strap molasses. Five feeding stations were established in a half circle about 30 m from the hives. Foragers (>100) were trained to accept sugar syrup at each feeding station. The foragers were permitted to collect sugar syrup at the feeding station in the morning before the trial. When sufficient foragers were visiting the feeding stations the sugar syrup was replaced with one petri-dish containing the jam bait (control) and five dishes of either 0.2, 0.5, 1, 2, and 5% oxalic acid in jam. The jam had been heated to 60°C to dissolve the oxalic acid. The baits were removed at the end of the day and weighed to determine the amount of jam consumed. The trial was repeated 5 days later with each concentration at a new location.

Attractiveness of molasses to opossums

A field trial was conducted near Maramarua State Forest (80 km NE of Hamilton). Bait stations (124) were set out on a 1.2 km track along the edge of the forest. Each bait station consisted of two pieces of turf (approximately 1 m apart) turned over. A jam bait was placed on one of the turfs and a 25% blackstrap molasses-jam bait on the second turf.

The number of baits consumed were counted on the second day. All the baits that were taken were then replaced with a cyanide bait to determine the type of animal that had been feeding on them. The bait stations were checked again on the following day and the number of dead animals recorded.

RESULTS

Exploitation of jam baits

Trial 1. All the baits that were laid around the hives were completely consumed by the bees within 8 h.

Trial 2. One load of the poison jam proved fatal for 62% of the foragers. The remainder appeared to recover from the early symptoms of 1080 poisoning with no ill effects. A number of other bees died several hours after the start of each trial. These were presumably house bees that received 1080-jam from returning foragers. The poison had a delayed action so that foragers showed no debilitating effects for up to 2 h after they had consumed the poison. The initial effects were a vigorous shaking, followed by an inability to hold onto the comb, and finally death. The earliest death (a bee lying on the floor of the hive without moving) occurred in 1.5 h.

Trial 3. The delayed action of the 1080 allowed foragers to make repeated trips to the poison permitting new foragers to be recruited to it. Fifty five percent of the foragers made more than one trip and two were recorded making four foraging trips to a 1080 bait.

Repellency of blackstrap molasses

Trial 1. The results of presenting foragers with different concentrations of molasses can be seen in Fig. 1. When given a choice of a number of different concentrations they consistently exhibited a preference for the bait with the lowest concentration of molasses. The amount consumed decreased with increasing molasses concentrations. The small reduction in weight of the baits with high concentrations of molasses, resulted from bait sticking to the legs and bodies of the foragers that came in contact with it plus a small amount of evaporation (< 2%). Removal of the lowest concentration of molasses caused increased feeding activity on the next lowest concentration.

By progressively removing the bait with the lowest molasses concentration it was possible to train bees to accept molasses concentrations in excess of 20%. Except when jam was presented, the foragers collected as much of the 20% molasses-jam baits when that was the lowest concentration, as they did of the 5, 10, and 15% baits, respectively when they were the lowest concentration presented.

Trial 2. The proportion of the baits consumed when foragers were only given a choice of a jam bait and one concentration of molasses-jam at each feeding station can be seen in Fig. 2. In the first replicate, the jam baits were readily accepted with a sharp decline at the 10% molasses level. The sharp decline in acceptability was only evident at the 20% molasses concentration in the second replicate. The variations in amounts of bait taken between replicates were probably because of variation in the number of foragers trained to each feeding station.

Repellancy of oxalic acid

Trial 1. The results of the sugar syrup oxalic acid trial have been presented in Fig. 3. The foragers consumed all the 0, 0.2, and 0.5% oxalic acid sugar syrup within 30 min. They had, however, collected less than half the 1% oxalic acid sugar syrup by the end of the hour and less than 12% of the 2 and 5% oxalic acid sugar syrup. The results of both replicates were similar.

Trial 2. The effect of presenting different concentrations of oxalic acid-jam at different feeding stations can be seen in Fig. 4. Almost all of the 0, 0.2, and 0.5% oxalic acid-jam was consumed, more than half of the 1%, but little of the 2 and 5% oxalic acid-jam.

Attractiveness of molasses baits to opossums

Both baits were consumed at 74 of the 124 (59.7%) bait stations, the jam alone taken at 2 of the stations (1.6%), and only the molasses-jam baits at 4 of the stations (3.2%). The only dead animals found the day after the cyanide baits were laid were 13 opossums.

DISCUSSION

From these results it can be seen that the 1080 poisoning of large numbers of bees results from the delayed toxicity of 1080. This permits foragers to make repeated trips to the baits allowing other foragers to be recruited. The effect is probably aggravated by the practice of laying pre-baits before the poison baits are laid. This allows foragers to become conditioned to visiting the bait stations before the poison baits are laid, increasing the possibility that the 1080 baits will be found and exploited by large numbers of honey bees.

The taste of the molasses-jam baits was unattractive to the bees, rather than the smell or visual aspect, as foragers landed on the baits and sampled them before leaving. Given a choice of baits with different concentrations of molasses, honey bees exhibited a preference for the bait with the lowest molasses concentration, indicating that they are able to detect small differences (5%) in molasses concentrations. The trials where the lowest concentrations were progressively removed have shown that honey bees can be trained to take baits with high molasses concentrations (20–25%). This result was not unexpected as honey bees have been shown previously to be able to be trained to take inherently unattractive compounds as long as they are associated with a reward (von Frisch 1967).

Foragers that have not been preconditioned will not readily accept concentrations of molasses in jam of $\geq 20\%$. However, it must be noted that some foragers consumed baits with an excess of 20% molasses. This was, however, where large numbers of honey bees had been trained to accept sugar syrup at a particular site and the syrup then replaced with molasses-jam baits. This would result in a higher degree of acceptance than normally seen under field conditions. Also, although some of the baits with high molasses concentrations were consumed, the feeding took place within a few hours of the baits being presented. The foragers discontinued feeding on the baits before they were consumed, suggesting that little would be consumed under field conditions.

To reduce the acceptance of molasses-jam baits even further it is important that the molasses is added to both the poison baits and the pre-baits (jam baits) that are usually laid the day before the 1080-jam baits. Failure to do this would result in foragers being trained to accept jam pre-baits which would increase the possibility of them accepting the molasses-jam 1080 baits.

Much higher concentrations of oxalic acid in jam baits were required to repel bees (1%–2%) than there is in 20% blackstrap molasses (contains < 0.2% oxalic acid). This indicates that repellency of molasses is not just a result of its oxalic acid component but also of some other compound or compounds. Oxalic acid has the advantage over molasses in that its addition to 1080-jam baits does not affect the consistency, colour, or odour of the baits.

From the trials with opossums it appeared that there were no strong preferences for either jam or molasses-jam baits, suggesting that molasses could be added to opossum baits. The lack of repellency of molasses to opossums was also supported by the trials in which it was incorporated with pellets (Morgan 1985). However, subsequent cage trials have suggested that the addition of molasses or oxalic acid can reduce the amount of the baits consumed by opossums but may still be able to be added to 1080-jam baits (Anon. 1989).

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