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ORIGINAL PAPER

The effect of water on the attractiveness and efficacy of a fast-acting ant bait

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Abstract Invasive ants are some of the most important environmental and economic pests globally, with granular corn-grit based baits being a common method of control. One of the limitations of these baits is their perceived ineffectiveness after rainfall or heavy dew, with control programs frequently suspending treatment due to these conditions. Empirical research to support or refute these restrictions, however, is lacking, and has not delineated the effects of water on the attractiveness of baits to ants and the effectiveness of baits in controlling colony activity. Here, we compare the number of ants interacting with baits (attractiveness) and the activity levels of colonies after baiting (efficacy) across wet and dry baits in the field, using *S. invicta* colonies in Queensland, Australia. Dry baits were removed by ants at a greater rate than wet baits, but more ants were observed interacting with wet than with dry baits. Dry baits outperformed control baits (with no active ingredient), but not wet baits, in supressing colony activity. These results suggest that the complete suspension of baiting during wet conditions may place unnecessary restrictions on management.

Keywords Invasive ants · Pest management · Baits · Rainfall · Weather · *Solenopsis invicta*

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Introduction

Invasive ants are some of the world's worst environmental and economic pest species, contributing to the loss of native biodiversity, disruption of ecosystem services, damage to infrastructure, and even posing serious health risks (Lach and Thomas 2008; Ward et al. 2008; Lenancker 2019; Siddiqui et al. 2021; Angulo et al. 2022; Lopez et al. 2024). By far the most common method of invasive ant control is through the application of chemical insecticides in baits. This technique was used in all 316 documented invasive ant eradication programmes as of 2016, of which 144 were recorded as successful (Hoffmann et al. 2016). Ant bait formulations typically consist of an active ingredient (insecticide) mixed with an attractant or phagostimulant (commonly soybean or other vegetable oil, or sugar based attractants) (Chen and Oi 2020). Although the active ingredient can vary, with both water-soluble and oil-soluble baits available, the most common insecticidal chemicals used in ant eradication are fipronil and hydramethylnon, or some combination of the two (Stanley 2004;

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Hoffmann et al. 2016). The fast-acting active ingredient indoxacarb is also now used in some baits and has achieved excellent colony suppression, particularly targeting the red imported fire ant *Solenopsis invicta* (Stanley 2004; NFAEP 2023; Syngenta 2023). The fire ant bait Advion® Fire Ant Bait contains 0.5 g/kg of indoxacarb as it's active ingredient (Syngenta 2023), and can reportedly kill colonies within 24–72 h (NFAEP 2023; Syngenta 2023).

Although baits have so far been the most effective method of invasive ant control and eradication, one of their most significant limitations is the tendency to degrade in wet conditions (Kafle et al. 2009, 2010; Cabral et al. 2017). Consequently, invasive ant control programmes may suspend baiting in wet conditions, placing serious seasonal limitations on control (Kafle et al. 2010; NFAEP 2023). While baits have been recorded to lose structural integrity when exposed to water, typically through the carrier matrix becoming waterlogged, few studies have explicitly investigated whether this physical degradation leads to significantly reduced attractiveness to ants and/or reduced suppression (Kafle et al. 2009, 2010; Oi et al. 2022). Advion®, for example, is among the baits shown to structurally degrade in wet conditions, but an effect of water on the actual efficacy of the bait has not been demonstrated (Kafle et al. 2010). More broadly, both bait attractiveness and efficacy can vary across species and formulations (Montgomery et al. 2015); Yeeles et al. 2021), highlighting the need for species-specific evaluation of factors such as environmental degradation.

Here, we use an invasive population of *S. invicta* in Queensland, Australia to compare the number of ants interacting with baits (attractiveness) and the activity levels of colonies after baiting (efficacy) across wet and dry baits in the field. *Solenopsis invicta* is native to South America and has been introduced into at least six countries outside its native range. In its introduced range *S. invicta* now covers 128 million hectares and is anticipated to spread further if not controlled (Morrison et al. 2004; Scanlan 2006; Gutrich et al. 2007; Adams et al. 2011; DPIRD 2020; Weeks 2023).

In Australia, the southeast Queensland infestation of *S. invicta* is the only population and is the focus of a multi-million-dollar national eradication program run by the Queensland Department of Agriculture and Fisheries and supported by all Australian states and territories. The National Fire Ant Eradication Program (NFAEP) is working to contain the species by creating a boundary through treatment plans that span 10-year periods (Wylie and Janssen-May 2016; Wylie et al. 2016; McNaught et al. 2019). Most of the colonies of *S. invicta* in this population are high-density monogyne (single *queen), allowing for greater natural dispersion due to higher elevations observed in mating flights (Shoemaker et al. 2006).

By experimentally applying different water treatments to baits and recording both their attractiveness to active *S. invicta* colonies and their effect on colony activity levels following bait application, this study provides a novel field test of the action of baits under different environmental conditions. Namely, this study tests whether: a) wet baits attract ants and are removed to the nest at different rates to dry baits, and b) wet baits suppress colony activity to a different extent than dry baits. The answers to these questions will provide important insights into optimal management planning for *S. invicta* in variable weather conditions.

Methods

Two experiments were conducted as part of this study: (1) an attractiveness experiment to determine the attractiveness of wet and dry baits, and (2) an efficacy trial to determine if wet baits suppress colony activity to a different extent than dry baits. Both were undertaken within the infestation of *S. invicta* in southeast Queensland, Australia. As this species was under an eradication program at the time of this study, sites were limited and identified through the NFAEP.

Attractiveness experiment

Study site

Twenty nests were located in Yatala, Queensland for use in the attractiveness experiment (Fig. 1 and 2). These nests were located on local council land with cattle grazing. A small creek ran through the site, however during the time of this study, the creek was dry. Nests were generally located in direct sunlight, or had a little shade covering them. This experiment was completed over a four day period (3/11/2022, 30/11/2022, 12/12/2022, and 19/12/2022).

Fig. 1 Map of the Brisbane area in Queensland, Australia, showing the location of the four sites. Map generated using QGIS (QGIS.org 2025)

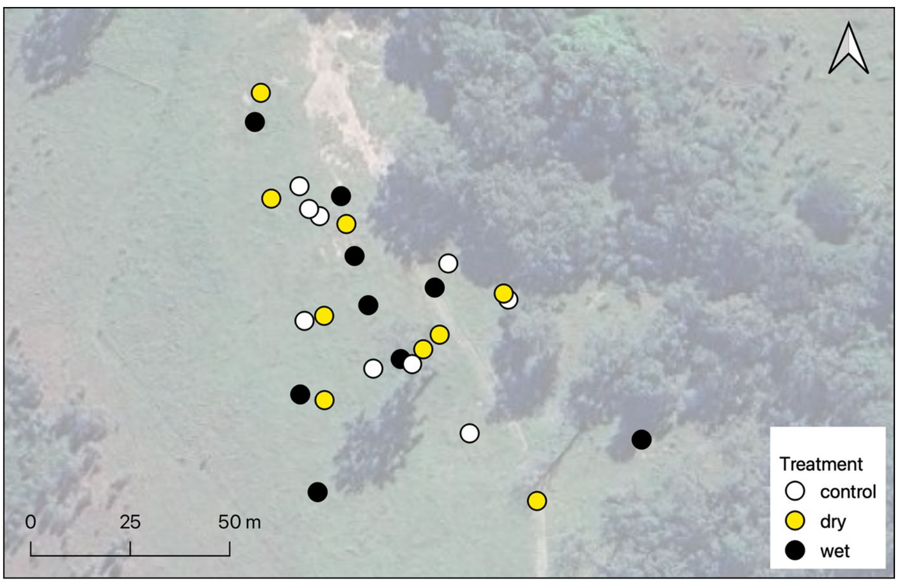

Fig. 2 Map of the Yatala site showing the location of fire ant nests and the Treatment applied to each nest. Map generated using QGIS (QGIS.org 2025)

Field methods

Three survey tiles (ceramic tiles approximately 20 cm × 20 cm, marked with a 1 cm × 1 cm grid pattern) were deployed per nest. On each tile, 60 granules of Advion® ant bait were divided into three groups of twenty granules. Each tile was divided into three equal sections, with each section assigned to one of three moisture Treatments: (1) Dry (no water applied), (2) Low (~ 1 ml water added to imitate dew or light rainfall), and (3) High (~ 10 ml water added to imitate medium to heavy rainfall). Moisture treatment levels were selected to reflect realistic environmental conditions in Brisbane (southeast Queensland, Australia) where the study was conducted. The Brisbane region experiences average daily rainfall of approximately 1–5 mm over the 3-month study period (BOM 2023).

To prevent the High and Low Water Treatments from contaminating the Dry Treatments, small barriers were placed around each section on the tile during application of the water. High and Low Water

Treatments were sprayed using a precise hand-held mister which was filled with 1 ml (Low Water) or 10 ml (High Water). Following moisture application, the walls were removed so that ants could access all three Treatments on a single tile in a buffet style choice experiment.

For each nest, three tiles were placed equidistant around the nest (each nest was roughly 20 cm by 30 cm by 20 cm). Over a 60 min period, observations were conducted every 10 min. We recorded the number of *S. invicta* workers interacting with bait granules and the number of bait granules remaining, for each Treatment on each tile. An interaction was defined as an individual ant directly engaged with a bait granule; ants present on the tile but not interacting with a granule were not counted. The start and finish times of each trial, along with the weather conditions during data collection, were also recorded.

Statistical analyses

All statistical analyses and plotting were performed in R (R Core Team 2022). Models used in the analysis were generated using the packages *lme4* and *ordinal* (Bates et al. 2015; Christensen 2022). Fixed effects were assessed using *car* (Fox and Weisenberg 2018), while plots were created using *ggplot2* (Wickham 2016). Post-hoc analyses were performed using *emmeans* (Lenth et al. 2025).

The number of granules remaining on the tiles, and the number of ants interacting with granules, in each time interval were analysed in terms of Treatment and Time (fixed effects) and their interaction using Poisson generalised linear mixed models (GLMMs). To avoid forcing a linear trend with Time in the model, Time was included as an ordinal (ordered categorical) predictor, rather than continuous. Nest and Tile within Nest were included as random factors to account for repeated measures and non-independence among samples caused by these variables. Rainfall and weather data were collected at the time of observation but were excluded from the analyses as they were confounded with Time. Overdispersion was assessed by comparing residual deviance with residual degrees of freedom (df) and was not considered to be significant if this ratio was less than two (McCullagh and Nelder, 1989). The model for the number of granules remaining was not overdispersed (ratio = 1.95), but the model for the number of ants interacting with baits was (ratio = 4.00). This overdispersion was accounted for by including an observation level random effect (Harrison 2014). The significance of fixed effects was assessed using Wald chi square test.

Post-hoc analyses were performed to compare each pair of water Treatments (dry vs low, low vs high, high vs dry) at each Day. Pairwise comparisons were made using *Z* ratio tests, applying the Tukey adjustment for multiple comparisons.

Efficacy experiment

Study site

To test the efficacy of baits under different moisture Treatments, activity levels of 99 nests (33 nests per Treatment) were assessed across four sites in southeast Queensland (Fig. 1). The first site, located at Yatala, was on cattle-grazed farmland and consisted of 27 nests (9 per Treatment) (Fig. 2). Due to logistical constraints associated with the availability of fire ant nests, some nests at Yatala were used in both the attractiveness and efficacy experiments, with a greater than 35-day interval between the two experiments. Prior to commencing the efficacy experiment, baseline activity was measured (see below) for all nests and was consistently high, indicating that nests were active at the start of the study.

The second site was in Bromelton and consisted of 12 nests (4 nests per Treatment). The nests at this site were located along the southern edge of a large cropping field that had been tilled previously (Fig. 3). The third site (located in Stapylton) consisted of 27 nests (9 nests per Treatment) located in sandy/rocky soil near a large sugarcane farm (Fig. 4). The final site was in Flagstone and consisted of 33 nests (11 nests per Treatment). This site was on the boundary of a large construction site where new houses where being built (Fig. 5). Many of the nests were located on a small rise covered in thick shrubs and bushes.

Field methods

Each nest was haphazardly assigned to one of three treatments: (1) a corn grit granular bait with no active ingredient (Control); (2) insecticidal Advion® bait with no added water (Dry), or (3) insecticidal Advion® with 20 ml of water applied

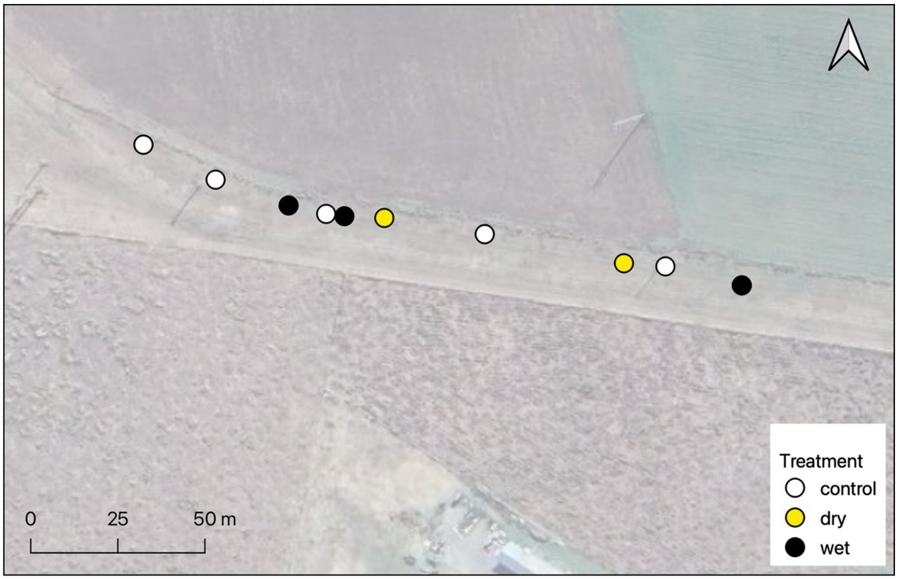

Fig. 3 Map of the Bromelton site showing the location of fire ant nests and the Treatment applied to each nest. Map generated using QGIS (QGIS.org 2025)

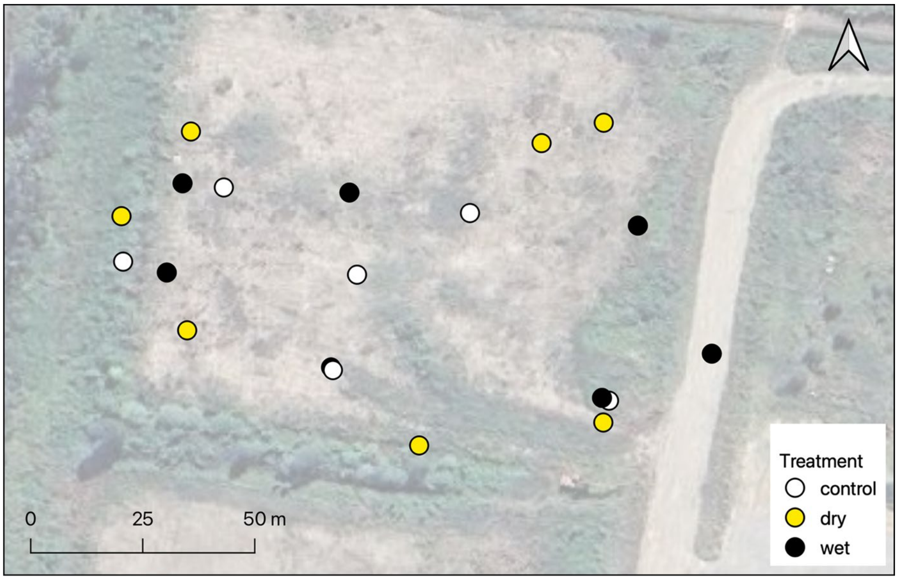

Fig. 4 Map of the Stapylton site showing the location of fire ant nests and the Treatment applied to each nest. Map generated using QGIS (QGIS.org 2025)

(Wet). For each Treatment 15 g (± 1 g) (approximately 1000 granules) of bait (blank or Advion®) was applied around the nest, as per the registered rate for treating a single fire ant nest (Syngenta 2023). The 15 g was placed into a small shaker container that was used to apply the bait to within a 30 cm radius around the nest mound. For the Wet Treatment, bait was sprayed with 20 ml of water using a spray bottle after application. This amount of water was sufficient to wet the bait without leading to ants evacuating the nest.

Activity of each nest was measured by estimating the number of ants that emerged after a minor disturbance, caused by tapping the top of the nest and inserting a stick into the nest. At each nest, activity was recorded for 20 s following the disturbance. Activity level was recorded as High if more than 75 ants emerged within 20 s of disturbance, Medium if between 25 and 75 ants emerged, Low if 1–25 ants emerged, and No Activity if no ants emerged. Activity was recorded on day 1 before treatment was applied, and subsequently on day 3, day 12, and day

Fig. 5 Map of the Flagstone site showing the location of fire ant nests and the Treatment applied to each nest. Map generated using QGIS (QGIS.org 2025)

21 following treatment to assess the short and long-term effects of baits. Rainfall three days before and throughout the observation period was also recorded, since it could interfere with the water content of the Treatments and foraging activity.

The majority of nest observations were conducted in the morning between 7:00 am and 8:30am, with four nest observations occurring in the late afternoon (from approximately 4 pm) due to logistical constraints. Trials began (i.e. Day 0 observations were made) on the 23/1/21, 3/3/23, 31/3/23, and 3/7/23 (see Supplementary Data). The afternoon observations were conducted on the 28/3/23, 3/4/23, 12/4/23 and 21/4/23.

Statistical analyses

Since activity levels were recorded as ordered categorical data, they were initially analysed in terms of Treatment (fixed categorical) and Day (fixed ordinal) using an ordinal mixed model. Time of Observation was initially included as a fixed effect but was removed as it did not improve model fit. Rainfall (mm) in the three days prior to each observation was initially included as an additional continuous fixed effect, however since Rainfall did not affect the action of baits it was removed from final models. Site and Nest (nested within Site) were included as random factors to account for non-independence of observations. This overall model encountered substantial convergence difficulties, and moreover was difficult to interpret due to the unexpected decline in activity in Control nests. To address these issues of model convergence while investigating the effect of Treatment on ant activity, we instead analysed the effect of Treatment separately on each Day.

Separate ordinal models were used to assess differences in activity levels between Treatments in each of these subsets. Assumption testing followed the same procedure described above. Brant tests were used to assess the parallel regression assumption of ordinal models. The parallel regression assumption did not hold Day Three, but held for Days 12 and 21 (Day Three overall $\chi^2_4 = 12.85$, $p = 0.01$; Day 12 overall $\chi^2_4 = 3.02$, $p = 0.55$; Day 21 $\chi^2_2 = 7.68$, $p = 0.1$). To account for the failure to adhere to the assumption of parallel regressions, a multinomial model was also employed to analyse the effect of Treatment on Day Three. Multinomial models do not rely on the assumption of parallel regressions, and therefore if the ordinal and multinomial models report the same conclusions the models can be interpreted with more confidence. Within each data subset, post-hoc contrasts were again performed for each Treatment level pair, with the Tukey adjustment for multiple comparisons.

Results

Attractiveness experiment

There were significant Time by Treatment interaction effects on number of ants interacting with baits ($\chi^2_2=372.78$, $p<0.001$) and number of granules remaining ($\chi^2_2=484.79$, $p<0.001$). Numbers of ants interacting with granules were highest at approximately the 20-min mark of the 60-min period, with the fastest increase and the highest peak in the High water Treatment, followed by the Low water Treatment, and finally the Dry Treatment (Fig. 6b). Post-hoc analyses confirmed significant differences between all Treatment pairs at all Time points except Time = 0 (Table 1).

The number of granules remaining in each Treatment declined over time (Fig. 6a), with a faster reduction observed in the Dry Treatment compared to the Low and High water Treatments. Post-hoc analyses confirmed different trends over time between each Treatment pair. There was a significant difference between Dry and High water baits at all Time points except Time = 0. There was a significant difference between Dry and Low water baits at all Time points except Time = 0 and Time = 10. There was no significant difference between High water and Low water baits at any Time point except Time = 60 (Table 2).

Efficacy experiment

According to the ordinal models performed separately for each day, the effect of Treatment on ant activity differed on different Days. Models were not

Table 1 Results of the post-hoc comparisons of the effect of water Treatment on ant activity at each Time point.

Time (min)	Contrast	*Z* ratio	*p*
0	Dry versus High water	-0.005	> 0.99
0	Dry versus Low water	-0.004	> 0.99
0	High water versus Low water	< 0.001	> 0.99
10	Dry versus High water	-5.77	< 0.001*
10	Dry versus Low water	-3.17	0.004*
10	High water versus Low water	2.82	0.01*
20	Dry versus High water	-8.56	< 0.001*
20	Dry versus Low water	-3.19	0.004*
20	High water versus Low water	5.81	< 0.001*
30	Dry versus High water	-9.57	< 0.001*
30	Dry versus Low water	-4.81	< 0.001*
30	High water versus Low water	6.10	< 0.001*
40	Dry versus High water	-9.05	< 0.001*
40	Dry versus Low water	-5.12	< 0.001*
40	High water versus Low water	5.61	< 0.001*
50	Dry versus High water	-7.29	< 0.001*
50	Dry versus Low water	-4.48	< 0.001*
50	High water versus Low water	5.96	< 0.001*
60	Dry versus High water	-5.64	< 0.001*
60	Dry versus Low water	-3.29	0.003*
60	High water versus Low water	6.15	< 0.001*

* = significant difference between Treatment pairs

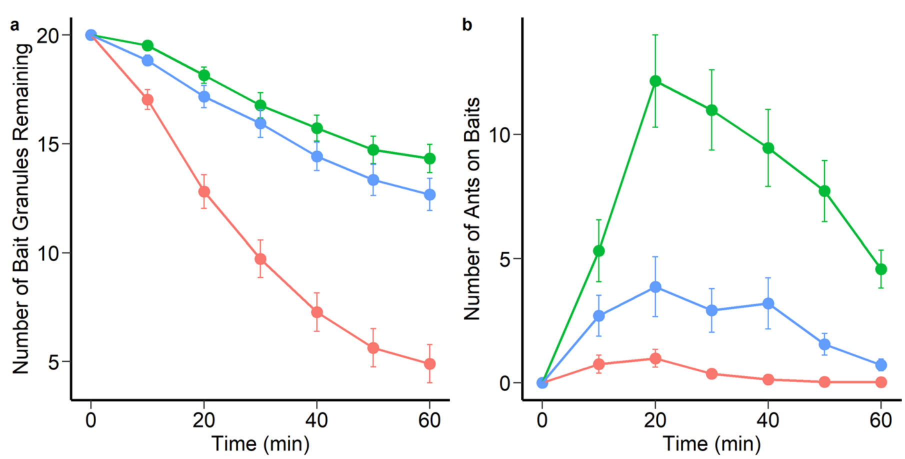

Fig. 6 Mean (± SE) number of bait granules remaining on each tile (a) for Dry, Low Water (blue), and High Water (green) Treatments, and mean (± SE) number of *Solenopsis invicta* workers interacting with Dry (red), Low Water (blue), and High Water (green) baits (b), over 60-min observation periods

Table 2 Results of the post-hoc comparisons of the effect of water Treatment on number of baits remaining at each Time point

Time (min)	Contrast	Z ratio	p
0	Dry versus High water	< 0.001	> 0.99
0	Dry versus Low water	< 0.001	> 0.99
0	High water versus Low water	< 0.001	> 0.99
10	Dry versus High water	-3.18	0.004*
10	Dry versus Low water	-2.33	0.052
10	High water versus Low water	0.86	0.67
20	Dry versus High water	-7.42	< 0.001*
20	Dry versus Low water	-6.16	< 0.001*
20	High water versus Low water	1.28	0.41
30	Dry versus High water	-10.49	< 0.001*
30	Dry versus Low water	-9.41	< 0.001*
30	High water versus Low water	1.13	0.49
40	Dry versus High water	-13.33	< 0.001*
40	Dry versus Low water	-11.67	< 0.001*
40	High water versus Low water	1.83	0.16
50	Dry versus High water	-15.02	< 0.001*
50	Dry versus Low water	-13.29	< 0.001*
50	High water versus Low water	2.02	0.11
60	Dry versus High water	-15.88	< 0.001*
60	Dry versus Low water	-13.84	< 0.001*
60	High water versus Low water	2.46	0.037*

Significant *p* values are indicated by *

performed for Day 0 as all nests had high activity. On Day 3, there was a significant effect of Treatment on ant activity ($\chi^2_2 = 12.01$, $p = 0.002$; Fig. 7). According to the post hoc tests, Dry baits significantly reduced activity compared to Controls ($Z = 3.26$, $p = 0.003$), but there was no significant difference between Controls and Wet baits ($Z = 2.11$, $p = 0.089$) or between Dry and Wet baits ($Z = -1.36$, $p = 0.36$) (Fig. 7). Given that the parallel regression assumption did not hold for the overall model, these results were compared to those from the multinomial equivalent for Day 3. According to the multinomial model, there was no significant effect of Treatment on ant activity at Day 3 ($\chi^2_2 = 5.47$, $p = 0.48$). The results for Day 3 should therefore be interpreted with caution. On Day 12, there was also a significant effect of Treatment on ant activity ($\chi^2_2 = 6.12$, $p = 0.047$). Again according to the post hoc tests, Dry baits significantly reduced activity compared to Controls ($Z = 2.37$, $p = 0.047$), but there was no difference between Control and Wet baits ($Z = 0.77$, $p = 0.72$) or between Dry and Wet baits ($Z = -1.69$, $p = 0.21$) (Fig. 7). On Day 21, there was still a significant effect of Treatment on ant activity ($\chi^2_2 = 10.61$, $p = 0.005$). According to the post hoc tests, Dry baits significantly reduced activity compared to Controls ($Z = 3.09$, $p = 0.006$). Wet baits seemed to reduce activity compared to Controls at this time point, but this result was marginally non significant ($Z = 2.28$, $p = 0.058$). There was no difference between Dry baits and Wet baits ($Z = -1.00$, $p = 0.57$) (Fig. 7).

Discussion

The results of this study show that water content influences the attractiveness of of Advion® baits, with wetter baits attracting more ants than drier treatments. Despite this, dry baits were the most effective at reducing ant activity, with mixed evidence for an effect of wet baits on ant activity. In the attractiveness experiment, ants retrieved granules from both wet and Dry Treatments. Although granules were retrieved more rapidly from the Dry Treatment, more ants were found interacting with the Wet Treatment. Moreover, while dry granules provided the clearest reduction in ant activity compared to control nests, there was no significant difference in activity suppression at any time point between nests treated with wet and dry granules. Although there was also no significant difference in ant activity between wet granules and controls at any time point, this difference was marginally non-significant at later time points. These results are complicated by the fact that control nests also showed unexpected changes in activity levels post-treatment. Nevertheless, the complete suspension of baiting activities in wet weather may therefore be an unnecessary limitation to management, and further avenues that allow baiting to continue in these conditions should be explored.

In the attractiveness experiment, dry ant bait granules were removed from the tiles faster than wet bait granules, although there was a significant decline in the number of granules remaining over time in all

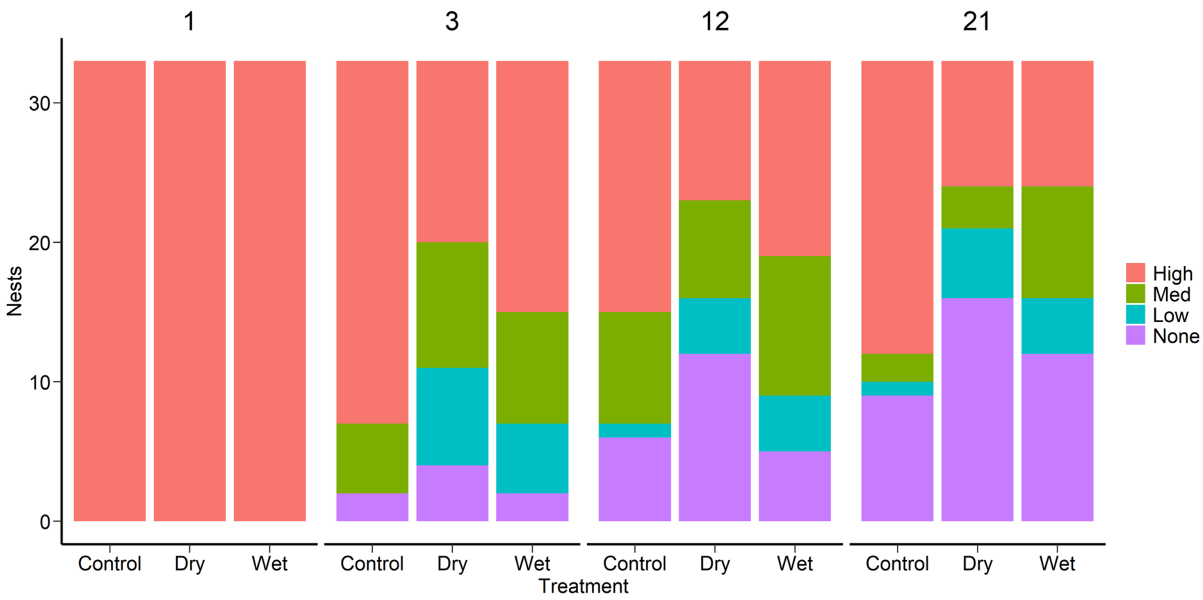

Fig. 7 Bar plot showing the activity levels of all 99 *Solenopsis invicta* nests (33 nests per Treatment) across all sites for the efficacy experiment. Numbers at top of plot refer to number of days post-treatment observations were taken

three Treatments. In this experiment, Advion® with a bait matrix of corn grit soaked in a mix of insecticides and oil was used. When water is applied, the granules form a thick paste or mushy substance, which appears to be harder for individual ants to pick up than single dry granules (Oi et al. 2022). In contrast, in the Dry Treatment, single workers could easily carry individual dry bait granules back to the nest, resulting in a higher removal rate.

More ants were observed interacting with wet bait granules than with dry granules. Furthermore, ants spent longer interacting with wet granules (High Treatment) than dry granules. *Solenopsis invicta* workers feed predominantly via liquid feeding, 'sucking up' nutrients from the food source before returning to the colony (Tennant and Porter 1991). Workers then feed larvae via trophallaxis (Petralia and Vinson 1978; Cassill and Tschinkel 1995). Liquid feeding was observed in the Low and High Treatments, and the results of the efficacy experiment suggest that the active ingredient of the bait may be transferred to the nest via this pathway even when the solid bait matrix has been compromised by water. While nests treated with dry granules seemed to have the lowest activity levels, the post-hoc analyses reported no significant difference between wet and Dry Treatment nests. Nests treated with either granule type had significantly lower activity levels than control nests. Wetting the bait granules therefore does not reduce the integrity of the active ingredient (indoxacarb) sufficiently to render the bait ineffective.

We found no significant differences in efficacy between wet and dry treatments. This suggests that any reduction in retrieval rate in the attractiveness trial did not translate into reduced colony-level impacts. Together with the higher levels of ant activity observed at wetter baits, these findings suggest a trade-off between attraction and retrieval efficiency under different moisture conditions. Consequently, bait matrices that maintain structural integrity while retaining high attractiveness under wet conditions may further optimise bait performance. For example, hydrophobic baits developed in Taiwan using a shrimp shell carrier rather than a corn grit carrier (Erasant®) have been shown to be more effective under wet field conditions (Van der Meer and Milne 2017). Although these baits still clump and soften when wet, they dry and separate more rapidly than conventional corn grit baits (Oi et al. 2022). Furthermore, hydrophobic baits remain palatable to *S. invicta* following water exposure (Van der Meer and Milne 2017; Oi et al. 2022) and may therefore enhance bait performance under wet conditions.

One unexpected result from this study was that control nests showed reduced activity over time relative to day one observations, despite receiving baits with no active ingredient. It is possible that these unexpected activity levels may be due to variable colony structure, with both polygynous and monogynous colonies being present in *S. invicta*. If colonies were polygynous, workers from the same colony may have foraged baits from both control and Treatment nests. While high nest densities, as seen in this study, are characteristic of polygynous colony structures (Greenberg et al. 1985), in southeast Queensland less than 2% of the *S. invicta* population is polygynous, and high-density monogyne colonies are common (Henshaw et al. 2005). Nests were therefore assumed to be independent, although cross-contamination of workers (and baits) among nests cannot be ruled out, and multiple nest entrances can exist even in monogyne colonies.

Observing no activity at a nest does not necessarily indicate that no living ants remain. Advion® is a fast-acting bait and has been recorded to kill colonies within 24–72 h post-exposure (NFAEP 2023). However, for colony death to occur the queen must consume a lethal dose of indoxacarb. If baits are distributed around the colony by the foraging workers without a lethal dose being consumed by the queen, this could lead to an initial reduction in foraging activity followed by a gradual recovery (Fletcher et al. 1980). This is one possible explanation for some of the patterns seen in our experiments, with fluctuating activity levels observed in some nests rather than a uniform reduction over time post-baiting.

Although environmental conditions varied during the trial period, no corresponding effect on bait performance was detected. Rainfall was recorded during the study and may have contributed to variability in nest activity measurements, however this variation did not translate into differences in overall bait efficacy, as both wet and dry treatments performed similarly. This suggests that the observed treatment effects were robust to short-term environmental fluctuations under field conditions.

The results of both the attractiveness study and the efficacy did not demonstrate conclusive evidence for improved performance of dry as opposed to wet baits, in terms of both bait uptake and colony suppression. For management of invasive ants such as *S. invicta*, while the best results may be achieved when rain is not forecast for 24 h pre-treatment, the complete suspension of baiting activities during wetter periods may not be necessary. More research is warranted into the effect of water on the chemical makeup of baits, including both the bait matrix and the active ingredient. Managers should also investigate the use of water-resistant or hydrophobic bait types and their potential benefits for use in controlling the spread of invasive ants where weather may have a detrimental impact on management.

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Author contributions JR, MT, and AM conceived of and designed the study. JR performed the field experiments, collected data, and prepared the majority of this manuscript. MT, AM, and SL provided academic supervision and reviewed and edited the manuscript. SL provided statistical support and final preparation of the manuscript for publication.

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Data availability All data and R codes are provided as Supplementary Information.

Declarations

Conflict of interest All authors declare no competing interests.

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