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CONTROLLING INVASIVE EUROPEAN WASPS (HYMENOPTERA: VESPIDAE) IN AUSTRALIA WITH BAIT

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Abstract The efficacy of YJX-100 yellowjacket baiting system to control individual nests and to provide area-wide suppression of European wasps *Vespula germanica* was evaluated. The study was conducted in a disturbed urban tall grass habitat in Canberra, Australia in 2017. Six active European wasp nests were targeted with bait application. Bait (3 grams) was dispensed in pill bottles with eight bait stations placed around each of target nests covering an area of approximately 0.4 hectare. Immediately after bait application, European wasps exhibited strong foraging response to the bait, requiring rebaiting within 60 minutes of initial bait application on ~90% of the bait stations deployed. At 24-hours post-baiting, the average traffic rate of the targeted nests of European wasps was reduced by 92.7%. Similar reduction (96.6%) in nest activity was achieved against colonies that were not directly targeted by bait application within the experimental area. None of the nests recovered and complete colony elimination was further confirmed by the excavation of the 6 nests targeted with bait application.
Key words Vespula, YJX-100, fipronil, baiting, control, Australia

INTRODUCTION

The European wasp, *Vespula germanica* is one of the globally important social Hymenoptera species, (Thomas, 1960; Edwards, 1976; MacDonald et al., 1980; Akre et al., 1981; Archer, 1998; D'Adamo et al., 2002). European wasp is also considered a major invasive pest in Australia (Spradbery and Maywald, 1992). In Australia, colonies of European wasps undergo a typical annual cycle characteristic of the species. Briefly, colonies are founded in the spring by single inseminated overwintered queens. Once the first cohort of workers emerges, the colony enters into a period of rapid growth. Both the number of workers and the size of the nest increase substantially in this phase. During late summer colony resources shift towards the production of reproductive caste, and with fewer workers emerging the colony enters into a phase of slow decline. After the death of the founding queen, the nest may continue to generate small numbers of workers, drones and queens until cold weather eventually kills the colony. In general, the stinging risk posed by European wasps to residents of Canberra (Australian Capital Territory. ACT) predictably rises during the summer-autumn months because colonies of the European wasps become larger and more aggressive as the season progresses. To protect residents from the stinging hazard poised by invasive European wasps the Municipal Services of ACT along with its private partner organization, the European Wasp Awareness & Entomological Advice Services, wage an annual aggressive search and destroy campaign against European wasp nests during the months of autumn (March, April, May). European wasp nests are either found by visual search by the members of the response team or by citizen complaints. Locations of confirmed European wasp nests are posted on a downloadable app (the eWasp Hotline) providing real-time information on the existing risk areas to the residents of Canberra. Due to the danger that European wasps pose to the public, confirmed nests in public areas are destroyed as soon as possible by qualified personnel utilizing an insecticidal dust product. The current approach aimed at combating European wasps by targeting individual and identified nests is not only highly labor and time intensive but also inherently inefficient and reactive.

Beyond monitoring, trapping, and direct nest destruction, wasp abatement efforts historically utilized toxic baiting against European wasps and other wasp species (Wagner and Reierson, 1969; Spurr, 1993; Spurr et al., 1996; Braverman et al. 1998; Harris and Etheridge, 2001; Sackmann and Corley, 2007, Rust et al., 2010, 2017). The underlying mode of action of toxic baits is their ability to provide an attractive and competitive food resource for foraging wasps while facilitating the delivery of the insecticide directly into the colony. To limit non-target exposure, toxic baits employed in wasp abatement utilize protein-based food matrix aimed at selectively projecting all the necessary sensory requirements to scavenger wasps (Wood et al., 2006; Sackmann and Corley, 2007; Rust et al., 2010, 2017). The food matrix is combined with an insecticide that is non-repellent, relatively slow acting, and preferably provides both contact and ingestive toxicity. Insecticides with horizontal transfer attribute are effective against wasps due to the nutritional ecology of these species. Among suitable insecticides, the phenylpyrazole insecticide, fipronil, has been tested against different species of wasps (Harris and Etheridge, 2001; Rust et al., 2010, 2017).

While generally effective, toxic baiting has not gained wide use in wasp abatement because of the lack of commercially available bait products. In recognition of the risk that stinging Hymenoptera poses to the public and various industries, e.g., agriculture, recreation, and food MGK, a Sumitomo Chemical Group Company (Minneapolis, United States of America), developed and successfully registered a wasp baiting system (YJX-100) in the United States of America in 2018. The YJX-100 baiting system comprises a highly attractive protein bait matrix combined with the insecticide fipronil (0.10%), and a bait station system. The objectives of this study were two-fold: 1) to assess the efficacy of the YJX-100 baiting system under Australian conditions in controlling identified colonies of invasive European wasps and 2) to assess the impact of such targeted bait application on the suppression of other European wasp colonies within the deployment area (area-wide suppression).

MATERIALS AND METHODS

Test site. The study was conducted in Pialligo a suburb of Canberra, Australia, in 2017. Thirteen European wasp nests were located along the banks of the Molonglo River. The riverbank of the Molonglo River is characterized as a disturbed urban tall grass habitat interspersed with eucalyptus, large patches of invasive blackberries and fennel. Seven nests were located on the west side of the Molonglo River along an approximately 625 m transect of the riverbank between ~15 m to 30 m from the river. The remaining six nests were located on the east side of the Molonglo River along an approximately 800 m transect of riverbank between ~12 m to 60 m from the river. Among the 13 identified nests, the 6 nests furthest apart from each other were selected for directed bait application in order to achieve the maximum separation distance between treated nests within the existing distribution of known nest sites. The minimum separation distance between targeted nests was ~221 m. The remaining 7 nests were was monitored to quantify the impact of the baiting program targeted at specific colonies on other European wasp colonies residing within the general area of bait application (area-wide suppression). A further four nests were assigned to an untreated control group to document the natural nest phenology of European wasp during experiment, to validate the proposed experimental approach of assessing treatment efficacy by comparing nest activity before and after bait application, and to assess the impact of potential adverse weather conditions on colony response. Three of the four nests located were found along a bicycle path by the Molonglo River ~800 m from the nearest experimental nest and the fourth nest was located ~13 km away in Belconnen. Daily monitoring of the Belconnen nest site was not always possible.

Post-treatment traffic rate assessment. Prior to bait application, three pre-treatment assessments of traffic rate (2, 3 and 4 April, 2017) were conducted on all nests. Foraging activity (traffic rate) was estimated by counting the number of workers entering and exiting the nest per minute over a 5 minute period (Malham et al., 1991).

Bait application. Bait application was conducted on 4 April, 2017. Bait was dispensed in 118 ml pill bottles with three 12 mm holes drilled around the circumference of the bottle to allow access to the bait for the European wasps. Eight bait stations were placed around each target nest covering an area of approximately 0.4 ha based upon the label application rate. The treatment area for each nest was approximated by a rectangular shape overlaid on the distribution of bait stations targeting each nest. Bait stations were deployed around each target nest but adjusted to restrictions posed by the landscape surrounding each nest. The following major landscape obstacles were encountered during bait station deployment: the Molonglo River; the very steep riverbank of the Molonglo River; a creek blocking access to a quadrant, adjacent agricultural land; roads; fence lines; and large patches of invasive blackberry. Bait stations were hung on trees when possible or deployed approximately 1.2 – 1.5 m above the ground on standard sized wooden stakes to prevent tampering by animals. The shortest distance between a bait station and the target nest was 12 m and the longest distance was 87 m. Each station was pre-weighed using a portable laboratory scale (Digitech

QM7259) and then filled with 3.0 grams of commercial bait on the morning of 4 April, 2017. No chemical attractant was used in the study. Due to the strong foraging response to the bait, rebaiting was necessary within 60 minutes of initial bait application at most bait stations. An additional 6 grams of bait was introduced into each stations that reached the rebaiting threshold (75% of bait removed). To account for mass loss due to dehydration of the bait during its deployment, 6 modified bait stations containing 3 grams of bait were set during initial bait application. The openings of these stations were covered with a mesh screen to prevent access and bait removal by European wasps.

Post-treatment traffic rate assessment. Daily traffic rate assessments were conducted for all nests for 7-days post-bait application using the same methodology as used for pre-treatment traffic rate assessment. Additional post-treatment traffic rate assessments were made on 9, 16, 23, and 32-days post bait applications. Traffic rate assessments were carried out during peak foraging activity of European wasp colonies.

Nest retrieval. To assess potential colony recovery, baited nests were monitored for an additional 4 weeks after which they were excavated (6 May, 2017). In order to prevent animals from destroying defenseless colonies, the entrances of each nest targeted with bait applications were marked and secured with heavy duty wire mesh on 11 April, 2017 (7 DAT-Days After Treatment). Nests were excavated using hand tools: pick axe, hand shovel and screw driver.

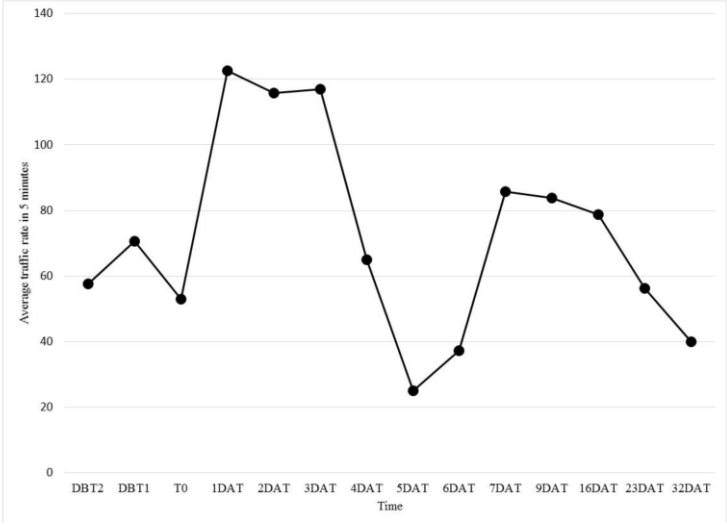
Data analysis. Pre-treatment nest traffic was compared with post-treatment nest traffic using paired-samples t-test (Statistix 9, Tallahassee, FL).

RESULTS AND DISCUSSION

Environmental conditions. Prevailing weather conditions were favorable during the study in Canberra facilitating robust European wasp activity which created a significant public nuisance and corresponding challenges to ACT Services staff. No critically adverse weather event was encountered during the course of the study. The average temperature from 2 to 11 April was fairly stable – average temperature at 9.00 AM, 12.00 PM and 3.00 PM was 13.3 °C, 16.8 °C and 18.2 °C, respectively. Only a single short duration weather event was encountered during the study between 9 and 10 April, 2017 (5-6 DAT). There was fairly heavy rain between 9.00 AM on 9 April to 10 April (~13 mm) and cooler temperatures on both days, however the temperature recovered by 11 April. Apart from this period there was very little rainfall during the study and the average rainfall was only 0.9 mm in April and 0.03 mm in the first six days of May. Temperatures did drop slightly through April and early May, maximum temperatures in the first 3 days of the study on 2-4 April were 20.4, 18.4 and 18.7 °C and for the last three days of the study on 4-6 May were 17.6, 19.1 and 17.3 °C, respectively. These later temperatures were still mild and there was significant European wasp activity in the untreated areas of Canberra from our own observations and reports to ACT Services staff.

Colony activity of untreated control nests. The mean pre-treatment traffic rate of the untreated control colonies was 62.9 worker per minute indicating large active European wasp colonies. All untreated control colonies remained active during the 32-day post-baiting data collection period with a mean traffic rate of 40.0 worker per minute at the final 32-day post-baiting assessment. Nest activity of untreated controls remained high for 4 days after bait application when a weather event temporarily curtailed nest activity between 5 to 6 DAT (Figure 1). Traffic rate almost doubled across the untreated 3 nests (no data from Belconnen) during first 3-days of post-baiting, but due small sample size the difference was not significantly different from pre-treatment traffic rates ($t(2) = -4.81$, $P = 0.0406$; $t(2) = -3.99$, $P = 0.0576$; $t(2) = -2.64$, $P = 0.1185$; and $t(2) = 0.40$, $P = 0.7309$, at 1, 2, 3 and 4 DAT, respectively).

Figure 1. Nest traffic rate of untreated control colonies of European wasps during the study (Canberra, Australia, 2017). .DBT= Days Before Treatment, T0= Treatment Day, DAT= Days After Treatment



Bait acceptance and removal. Attractiveness, palatability, and recruitment to the bait was high. Foragers of European wasps discovered bait placements almost immediately after bait deployment. Within 30-60 minutes after initial bait application, 83% of bait stations each containing ~3.0 gram of bait (mean = 3.04 g, SD = 0.02 g) were

completely emptied, i.e., all bait was removed. Out of the 48 bait stations deployed in this study, only 5 (10.4%) did not need rebating. Overall bait removal was very high with 69.2% of the applied bait removed from the stations. One the day after bait application (1 DAT) no foragers were seen in or around the bait stations. Foragers were not observed in or around bait stations during the later sampling dates which correlates with the rapid reduction of nest traffic observed in all monitored nests in the area.

Colony response to targeted baiting. Bait application resulted in a rapid reduction in colony activity in the targeted nests of European wasps. At 24-hours post-baiting, the average traffic rate of the targeted nests was reduced from pre-treatment counts by 92.7% across the 6 nests targeted ($t(5) = 5.77$, $P = 0.0022$, Table 1). Each nest was also probed for defense reaction by stomping on the nest entrance during the 24-hour traffic rate assessment. None of the targeted nests responded to the simulated disturbance with defense reaction providing further evidence that the application of YJX-100 baiting system rapidly eliminated the stinging hazard posed by large European wasp colonies. Nest traffic rate continued to decline post-baiting as the remaining workers perished due to intoxication and/or affects related to the overall collapse of the colony (97.1%, 98.9%, and 99.4% at 2, 3 and 4 DAT, respectively). There was no rebound in worker activity in any of these nests during the remainder of the study. Similarly, stomping on the nests during subsequent data collections did not trigger defense reactions in any of the colonies further supporting the data that the stinging hazard posed by these colonies was practically eliminated 24-hours after bait deployment.

Table 1. Effectiveness of YJX-100 yellowjacket bait system to control colonies of European wasps, Canberra, Australia, 2017. .

Nest ID	Average Pre-Bating Traffic Rate	% Reduction of Traffic Rate[1]							
		1DAT	2DAT	3DAT	4DAT	5DAT	6DAT	7DAT	9DAT
1	44.7	99.6	100.0	99.6	100.0	100.0	100.0	100.0	100.0
2	122.9	96.4	98.0	99.7	99.7	99.8	100.0	99.8	100.0
3	100.9	92.5	99.8	99.6	99.8	100.0	99.8	100.0	100.0
4	111.0	95.9	99.6	99.6	100.0	100.0	100.0	100.0	100.0
5	41.1	84.4	90.3	97.1	97.6	100.0	100.0	100.0	100.0
6	126.1	87.3	94.8	97.6	99.4	100.0	99.7	100.0	100.0

[1]Traffic rate reduction was calculated on the basis of the average of 3 pre-treatment traffic counts for each nest (2DBT, 1DBT and T0). DBT= Days Before Treatment, T0= Treatment Day, DAT= Days After Treatment

Table 2. Area-wide suppression of European wasp activity by YJX-100 yellowjacket bait system in controlling colonies of European wasps that were not directly baited, Canberra, Australia, 2017. .

Nest ID	Average Pre-Bating Traffic Rate	% Reduction of Traffic Rate[1]							
		1DAT	2DAT	3DAT	4DAT	5DAT	6DAT	7DAT	9DAT
7	87.2	97.2	100.0	99.8	99.8	100.0	100.0	100.0	100.0
8	95.5	98.1	99.6	100.0	100.0	100.0	100.0	100.0	100.0
9	119.7	95.8	98.5	99.8	99.8	99.8	100.0	100.0	100.0
10	123.3	96.8	97.7	99.5	99.4	99.8	100.0	100.0	100.0
11	104.5	98.1	99.8	99.4	99.8	n/a[2]	n/a	n/a	n/a
12	116.1	93.6	97.9	99.0	99.3	99.7	100.0	100.0	100.0
13	212.5	96.5	99.6	99.3	100.0	100.0	100.0	100.0	100.0

[1]Traffic rate reduction was calculated on the basis of the average of 3 pre-treatment traffic counts for each nest (2DBT, 1DBT and T0). [2]Nest was excavated on 08 April, 2017 to assess the stinging incident risk posed by baited nests to the public. DBT= Days Before Treatment, T0= Treatment Day, DAT= Days After Treatment

Nest excavation. The entrances of all nests were overgrown with vegetation which were clear signs of lack of maintenance. Correspondingly, no defense reaction was encountered during the excavation at any of the nests. All

nests showed a loss of structural integrity due to advance stage of decomposition. In one case, the nest was not even found even though the nest entrance was clearly marked and there was no visible damage to the protective cover overlaying the nest entrance. It is likely that decomposition due to a lack of nest maintenance and local environmental factors led to the complete destruction of this nest. Inside the excavated nests, dead workers and reproductives were scattered throughout the nest suggesting the inability of the colony to mount a coordinated sanitation response in response to effects of toxic baiting. The combination of the lack of defense reaction in the treated nests along with advanced state of decomposition supports the rapid elimination of these colonies by YJX-100 baiting system.

Suppression of non-targeted colonies. Toxic baiting within the experimental area also elicited strong impact on colonies that were not directly targeted by bait application. At 24-hours post-baiting in the experimental area, the average traffic rate was reduced from the pre-treatment level by 96.6% across the 7 untargeted nests ($t(6) = 7.82$, $P = 0.0022$, Table 2). Visual observations indicated that the observed reduction in nest activity was likely due to bait acquisition by these colonies. Four foragers were observed carrying bait into one of the non-targeted colonies. Traffic rate reduction also corresponded with the reduction of stinging hazard posed by these nests. Each nest was probed for defense reaction by stomping on the entrance at the 24-hour traffic rate assessment and then onwards for the rest of the duration of the experiment. None of the colonies responded to the simulated disturbance with a defense reaction indicating that the stinging hazard posed by these European wasp colonies was completely eliminated. Nest traffic rate continued to decline as the remaining workers perished due to intoxication and/or affects related to the collapse of the colony (99.0%, $t(6) = 7.73$, $P = 0.0022$; 99.6%, $t(6) = 7.81$, $P = 0.0022$; and 99.7% $t(6) = 7.75$, $P = 0.0022$; at 2, 3 and 4 DAT, respectively). There was no rebound in worker activity in any of these nests during the remainder of the study.

CONCLUSIONS

The prevailing weather conditions in 2017 were highly favorable to European wasps in Canberra which created a significant public nuisance and corresponding challenges to ACT Services staff. The robust European wasp activity provided an opportunity to evaluate the attractiveness and efficacy of YJX-100 baiting system within the Australian resource context. The protein-based matrix of YJX-100 baiting system was attractive and highly palatable to local European wasp colonies. The combination of the highly attractive food matrix with fipronil, a highly effective bait toxicant with horizontal transfer attribute provided a rapid reduction in foraging activity of large colonies of invasive European wasps within the experimental area. By 24-hour post-baiting European wasp foraging activity declined dramatically in the experimental area from both targeted and non-targeted colonies. None of the colonies recovered after baiting with YJX-100 baiting system because the rapid removal of the worker caste triggered a cascade of events that predictably led to the collapse of the colony. The rapid elimination of foraging workers is important from public health perspectives because of the aggressive foraging behavior and the propensity of these foragers to sting. YJX-100 baiting system was easy to deploy and it demonstrated an excellent proactive fit to supplement ongoing European wasp abatement efforts especially in areas with difficult access and unknown location and distribution of colonies.

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