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FORMULATION TECHNOLOGY TO IMPROVE WEATHER RESISTANCE OF RESIDUAL INSECTICIDES

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Abstract Suspend PolyZone is an insecticide with a unique formulation that contains a proprietary polymer that allows it to protect the active ingredient from weather, water runoff, and mechanical abrasion. This allows the product to leave behind residues that stay where they are applied and remain active in the environment for longer periods of time. To examine the residual longevity of Suspend PolyZone and other insecticides exposed to aging in outdoor environments, we introduced groups of either cockroaches or mosquitoes to different treated substrates and compared the mortality resulting from the insecticide residues. Suspend PolyZone was found to have the greatest residual activity and exhibited residual effects for the longest amount of time compared to the other insecticides, indicating that the properties of this formulation were effective in improving insecticide performance in outdoor environments.

Key words German cockroache, mosquitoes, pesticide residue, barrier treatments

INTRODUCTION

While insecticide use outdoors has been mainly to combat pest problems in agriculture, outdoor residential pest control services used to enhance the use of lawns, gardens, patios, and other landscape features by managing nonstructural pests have become more common (Templeton et al., 1999). Because these insecticides are exposed to outdoor environments, they are vulnerable to UV radiation which can breakdown the insecticide and translocation due to various weathering conditions (Takahashi 2003). This can increase the chance to contaminate non-target areas through pathways such as spraying, spray drifts, washoff and runoff (Mulla et al., 198; Rial-Otero et al., 2003; Lopez-Perez et al., 2006), and contribute to concerns about the adverse effects to human health and the environment, including the loss of non-target organisms and contamination of water and soil with insecticide residues (Younes and Galal-Gorchev, 2000; Arias-Estévez et al., 2008; Felix et al., 2019). In addition to contamination, movement of active ingredients in the environment can also decrease performance of the pesticide, potentially leading to increased call-backs to pest control companies, which can then lead to additional insecticide treatments. To alleviate these problems, it is necessary to develop insecticide formulations that improve the weather resistance of the active ingredients and allow the insecticide to remain where it is applied and to persist in the outdoor environment longer.

For an insecticide to be effective outdoors for longer periods of time, the active ingredient must be available to the target pest, and the chemical formulation should include components that protect the active ingredient and help it stay where applied. Improved formulations of insecticides can reduce off-target deposition, improve retention on target, and enhance uptake and translocation to the target organism (Arias-Estévez et al. 2008). Suspend PolyZone, a suspension concentrate insecticide manufactured by Bayer, contains a proprietary polymer that protects the active ingredient from weather, irrigation, and mechanical abrasion. Kijlstra et al. (2014) described this new formulation as an in-situ encapsulation technology, where an aqueous polymer dispersion forms a water-insoluble polymer film after spraying and drying. Unique polymeric and physical-chemical properties of this polymer were responsible for an improved residuality on porous, alkaline surfaces, wherein the polymer particles act like a protecting primer and only partially encapsulate the active microcrystals on the surface. It was subsequently demonstrated (Reid et al., 2015) that this in-situ encapsulation also protects the insecticide deposit from wash-off due to irrigation and precipitation, thereby improving residuality on outdoor surfaces.

Spraying insecticides in and around homes is a common practice to control a wide variety of insect pests. However, as the number of studies reporting the prevalence and distribution of indoor insecticide residues increases

(Wang et al., 2019), more residents may choose primarily outdoor insecticide treatments. The application of a residual chemical barrier has been an effective strategy for using insecticides outdoors, particularly in pest management plans to prevent insects from moving inside the home. While barrier insecticide treatments have a long history in mosquito control programs (Stoops et al., 2019), the popularity of this use pattern has experienced rapid growth in recent years. However, there is a lack of comparative efficacy research on the most popular formulations in the use pattern.

METHODS AND MATERIALS

Cockroach exposure bioassays. The surfaces of ceramic tiles were sprayed with the appropriate insecticide treatment or an untreated control (water) and allowed to dry. Groups of a susceptible strain of adult male German cockroaches (*Blattella germanica*) were exposed to the surfaces, either for 30 minutes or 1 hour, transferred to a clean container containing a water and food source, and were observed for mortality through 24 hours after exposure. Average of three to five replicates (n = 5 or 10 cockroaches). After the initial bioassay, the tiles were exposed to sunlight and natural precipitation, and the bioassay was repeated at various intervals after weathering.

These methods were executed by different researchers with various insecticides in the following locations: the Bayer research station located in Clayton, North Carolina from April-July 2009, April-June 2011, April-August 2012, September-December 2017, and May-October 2019, Clemson University located in Clemson, South Carolina from June-September 2013 and June-September 2018, Purdue University located in West Lafayette, Indiana from December 2017-March 2018, and the University of Florida located in Gainesville, Florida from October-November 2019. The insecticides studied in these various trials included Suspend PolyZone (4.75% deltamethrin), Talstar (7.9% bifenthrin), Demand CS (9.7% lambdacyhalothrin), Fendona CS (3.0% alphacypermethrin), Onslaught FastCap (8.0% piperonyl butoxide, 6.4% esfenvalerate and 1.6% prallethrin), and Scion (5.9% gammacyhalothrin). Insecticide concentrates where diluted in water to labeled rates and applied to the tiles; dilutions rates can be referenced in Table 1.

Mosquito barrier treatments. The residuality of barrier spray deposits subjected to outdoor weathering was studied using a modified WHO method (WHO, 2006). At various intervals after treatment and weathering, surfaces were returned to the laboratory where adult *Aedes aegypti* or *Culex quinquefasciatus* mosquitoes were confined in 5-minute exposures to the treated surface before they were transferred to a clean container, provided with a water source, to monitor the development of mortality through 24 hours after exposure.

Insecticide concentrates where diluted in water to labeled rates and applied to vinyl siding, as would be common in residential construction, and to foliage of mature *Camellia japonica* plants, to represent barrier treatments to common landscape plants. After treatment, the surfaces were exposed to ambient weather and precipitation at the Bayer research station located in Clayton, North Carolina during the summer of 2021. The insecticides studied were: Suspend PolyZone (4.75% deltamethrin), Demand CS (9.7% lambdacyhalothrin), Talstar (7.9% bifenthrin), Fendona CS (3.0% alphacypermethrin), and Onslaught FastCap (8.0% piperonyl butoxide, 6.4% esfenvalerate and 1.6% prallethrin); dilutions rates can be referenced in Table 2 and 3.

RESULTS AND CONCLUSIONS

The results of the cockroach exposure bioassays demonstrate the residual activity of various insecticides by summarizing the results from multiple experimental studies using German cockroaches as an indicator species (Table 1). Although these experiments were performed at different times and places, there were similar results between the studies. Insecticide residues in Suspend PolyZone maintained high activity 12-13 weeks after the initial treatment and despite their being exposed to weathering in outdoor conditions; while the other products had excellent activity initially, they all lost efficacy overtime when exposed to outdoor weather, albeit at different rates. This indicated that the polymer-enhanced formulation of Suspend PolyZone was protected from weathering and could remain on the surface for longer periods of time. As seen with the testing with cockroaches, very similar patterns were observed in the tests with mosquitoes. Whether on vinyl surfaces or plant foliage, insecticide residues in Suspend PolyZone, being protected by the in-situ encapsulation, were able to better resist weathering than all other products. Loss of residuality seems to occur faster on the vinyl surfaces than on plant leaves but Suspend PolyZone out lasted all the other products included in this testing.

Table 1. Outdoor exposure efficacy of insecticide residues on ceramic tile against German cockroaches.

Treatment	Concentration	0-1 day	1 week	2-3 weeks	4-5 weeks	6-7 weeks	8-9 weeks	10-11 weeks	12-13 weeks
Suspend PolyZone	0.75 fl.oz., 0.03%	100.0	100.0	100.0	98.0	100.0	98.7	100.0	98.9
Talstar	1.0 fl.oz., 0.06%	100.0	n/a	100.0	100.0	40.0	n/a	n/a	0.0
Demand CS	0.4 fl.oz., 0.03%	100.0	100.0	84.5	20.5	28.6	22.1	33.3	17.3
Fendona CS	2.0 fl.oz., 0.05%	100.0	84.7	24.1	25.5	33.3	22.2	22.2	33.3
Onslaught FastCap	0.5 fl.oz., 0.062%	100.0	100.0	100.0	50.0	46.7	36.7	40.0	43.3
Scion	0.33 fl.oz., 0.015%	100.0	100.0	25.3	0.0	0.0	n/a	n/a	n/a
Untreated	n/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 2. Outdoor exposure efficacy of insecticide residues on vinyl surfaces against *Aedes aegypti* and *Culex quinquefasciatus* (n=6).

Treatment	Concentration[3]	1 day	2 weeks	4 weeks	6 weeks
Suspend PolyZone	0.75 fl.oz., 0.03%	100.0	88.3	100.0	91.7
Demand CS	0.4 fl.oz., 0.03%	100.0	100.0	27.1	28.3
Talstar P	0.5 fl.oz., 0.03%	100.0	73.3	30.8	45.0
Fendona CS	1.0 fl.oz., 0.025%	100.0	13.3	16.7	30.0
Onslaught FastCap	0.5 fl.oz., 0.062%	100.0	90.0	25.6	26.7
Untreated	n/a	3.3	3.3	3.3	16.7
Cumulative precipitation inches		0.00	0.32	2.13	5.05

Table 3. Outdoor exposure efficacy of insecticide residues on plant leaves against *Aedes aegypti* and *Culex quinquefasciatus* (n = 6)

Treatment	Concentration	1 day	2 weeks	4 weeks	6 weeks
Suspend PolyZone	0.75 fl.oz., 0.03%	98.5	100.0	100.0	100.0
Demand CS	0.4 fl.oz., 0.03%	100.0	88.2	87.7	89.1
Talstar F	0.5 fl.oz., 0.03%	100.0	82.1	96.9	49.9
Fendona CS	1.0 fl.oz., 0.025%	100.0	86.4	50.3	50.3
Onslaught FastCap	0.5 fl.oz., 0.062%	100.0	98.3	42.4	31.4
Untreated	n/a	7.6	4.4	5.8	4.4
Cumulative precipitation inches		0.00	3.16	7.33	10.26

Our experiences with Suspend PolyZone have demonstrated that insecticide formulations can be developed that resist the deleterious effects of outdoor weathering and continue to provide effective pest control when used outdoors. This superior residual performance of Suspend PolyZone can be leveraged to reduce the absolute rate of insecticides applied outdoors by reducing the frequency of (or number of) applications in an effective pest management program. Advances in the chemical formulations of pest control products can help ease both environmental and health concerns associated with outdoor insecticide use.

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