Final Report, QA-2285:

An evaluation of potential repellents for Botta's pocket gophers

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Pocket gophers are fossorial rodents that cause substantial damage to crops, reforestation, and property. We tested potential repellents to identify candidates to reduce irrigation tubing damage. We dipped carrot chunks in the test materials, using mineral oil as the solvent. Gophers prefer tuberous roots and, when kept in captivity, are often fed carrots as part of their maintenance diet. None of the materials tested proved effective as repellents, even at concentrations as high as 20% active ingredient or in combinations. Wood blocks soaked in a few of the repellents received nearly significantly less damage than the control blocks and could be looked at further as repellents. However, it appears that the quest for an effective gopher repellent will continue to elude researchers.

Introduction

There are numerous species of pocket gophers in North America with most species belonging to the genera *Geomys* and *Thomomys* (Nowak 1991). Pocket gophers cause various types of damage to agricultural and rangeland resources and to reforestation (Witmer and Engeman 2007). Pocket gophers (*Thomomys* spp.) are generally considered one of the most damaging wildlife pests in California (Marsh 1992, Clark 1994). A recent study estimated average losses ranging from 5.3–8.8% across a variety of crops in CA (Baldwin et al. 2013), with one study showing a loss of 36.5% of annual production in alfalfa in fields with high density gopher populations (Smallwood and Geng 1997). The most widespread pocket gopher in California is the Botta's pocket gopher (*Thomomys bottae*; Case and Jasch 1994).

Primary control options for pocket gophers include trapping, burrow fumigation with aluminum phosphide, and baiting with rodenticides (Baldwin 2012, Baldwin 2014, Barnes et al. 1982, Baroch and Poche 1985, Evans et al. 1990, Case and Jasch 1994, Witmer and Engeman 2007). Both trapping and burrow fumigation can be highly effective at controlling pocket gophers (Lewis and O'Brien 1990, Proulx 1997, Baker 2004), but are typically more time consuming and costly than baiting (Marsh 1992, Engeman and Witmer 2000). As such, baiting is often preferred by many growers, Pest Control Advisors, and Pest Control Operators. Three baits are used to control pocket gophers: strychnine, zinc phosphide and first generation anticoagulants.

Pocket gophers are also damaging sub-surface drip irrigation tubes in agricultural fields in California. Repellents might provide a measure of protection to this tubing, if an effective repellent(s) can be identified. The material would need to be added to the irrigation water, or used as a coating on the tubing. Past efforts to identify effective gopher repellents have generally shown little promise (Witmer et al. 1998, Witmer et al. 1997), with a few exceptions such as predator odors (Witmer et al. 1997, Lindgren et al. 1997) and capsaicin (Shumake et al. 1999, Sterner et al. 2005). An irrigation system company, Netafim Ltd., requested us to revisit this situation and conduct cage trials to identify some effective repellents that they could then test in the field. Colleagues in Germany, working on vole damage, have identified some potential candidates which they found to be effective repellents for voles. We tested a few additional materials, based on the results of published scientific literature (e.g., papers in Mason 1997). A number of these materials are used as bird repellents, a few are used as mammal repellents, and a few are used as insect repellents. Many are "essential oils" derived from plants and used in aromatic and other therapies. However, none are registered as pocket gopher repellents. The materials were considered to be mild irritants and potentially cause short-term irritation to the skin, eyes, gastrointestinal tract, mouth, and respiratory tract.

The objective of this study was to identify effective repellents to reduce damage by pocket gophers. We will determine the efficacy of the potential repellents on wild-caught Botta's pocket gophers in a climate-controlled animal room of the USDA National Wildlife Research Center (NWRC) in Fort Collins, CO. We hypothesized that one or more of these materials would exhibit a high level of irritation to the olfactory, taste, or trigeminal receptors. We further hypothesized that some of the test materials would exhibit a high repellency as determined by the amount of treated, preferred foods consumed by gophers using carrots as the preferred food item. We also monitored the amount of chewing done by gophers on treated wood blocks.

Methods

Pocket gophers (henceforth, gophers) used in this study were Botta's pocket gophers (*Thomomys bottae*) live-trapped in California and transported to NWRC, Fort Collins, Colorado. Gophers were kept in individual numbered shoebox cages in a climate-controlled animal room. The lights were always off unless staff had to do tasks in the room during which times the lights were manually turned on, but at only 25% normal intensity. The temperature was maintained at 70 ^{0}F with ambient humidity (~10-30%). They were fed a maintenance diet of rodent chow pellets, carrot chunks, and received water *ad libitum.* They were provided with bedding and a den tube, and material to chew on (wood chunks). There was a two week quarantine period before the study began. Gophers were randomly assigned to treatment and control groups with 3 gophers per group. Each group contained at least one male or one female. The weight, sex, cage number, and treatment of each gopher were recorded before the initiation of a trial. Gophers continued to receive the maintenance diet throughout the trial. On day 1 of the trial, one piece of carrot (each about 10-15 g) was added to each cage after it had been dipped in the repellent test material and weighed. Solutions of repellent test materials were made of the specified concentration by adding the chemical to mineral oil (the solvent used). Control gophers were maintained on the maintenance diet only throughout the trials. Prior to dipping, a piece of colored toothpick was stuck through the center of each treated carrot piece so that the remaining treated pieces could be identified from any remaining untreated pieces. One day later, any remaining treated carrot pieces were taken from the cage and the weight recorded before returning it to the cage for another full day. At the end of the 2-day exposure period the final weight of any remaining treated carrot pieces were removed, weighed, and disposed of. The concentration of repellent solutions was increased in each subsequent trial (Table 1). We also tried a few combinations of repellent materials (Table 1).

We conducted a final trial using gophers that had not been used before, but had a propensity to chew on the wood blocks. Wood blocks were soaked in a repellent solution for 24 hours. Then each block was weighed before being placed in one of the gopher cages. As before, before, there were 3 gophers per treatment group. Three gophers were in a control group which received a wood block that had been soaked only in the mineral oil. Three days later, the wood blocks were removed and weighed so that the total amount removed (in grams) by gopher chewing could be determined. Gophers were examined daily and notes on their condition were recorded. The Attending Veterinarian or an Animal Care staff was contacted if any gopher appeared to be in more than momentary pain or distress. All surviving gophers were euthanized and incinerated at the end of the study.

T-tests and ANOVA tests were used on some of the data sets to determine if a significant difference existed in consumption of treated carrots versus control carrots and between treated and untreated wood blocks.

Results and Discussion

A sizable number of potential repellents were tested in our study. Some of these are already known to have some repellency with certain vertebrate or invertebrate species. Additionally, some have been identified in research studies as having repellency to some rodent species (e.g., Cowan et al. 2014, Fischer et al. 2013). Unfortunately, we did not find any of the tested materials to show significant repellency during our trials with Botta's pocket gopher. This was true even when the concentration was increased and when we combined two or three of the active ingredients (see Tables 1 and 2). We started with relatively low concentrations (generally 5% active ingredient) because we assumed only a low concentration in crop irrigation water would be acceptable so as to not affect food crop flavor or other attributes. One test material appeared to show promise as a repellent after one day of feeding on the dipped carrots. This was 10% 2-undecanone (also known as methyl nonyl ketone). Only 53% of the carrots were eaten by the gophers versus 84% of the control carrots ($T = 2.18$, $P = 0.095$). However, after the second day, the differences in the percentages eaten was much less at 80% and 100%, respectively ($T = 1.58$, $P = 0.190$). One material tested, 5% bergamot oil, almost appeared to be an attractant with 99% of the dipped carrots eaten after 1 day versus the 77% of the control carrots. However, the difference was not significant ($T = 1.75$, $P = 0.156$).

In the second part of the study, we used wood blocks that had been soaked in the potential repellent materials (Table 2). Three of the materials tested had nearly significantly less gnawing of the wood blocks than the control blocks ($F = 3.82$, $P = 0.057$). These materials were 10% Pulegone, 10% 2-undecanone, and the combination of these active ingredients: 10% 2-undecanone, 10% black pepper oil, and 10% methyl anthranilate. These materials could be further researched for their potential as gopher repellents.

Materials that have repellency for a rodent species may not show repellency for other rodent species. For example, Fischer and others (2012) found methyl nonyl ketone (= 2-undecanone) to be effective with common voles (*Microtus arvalis*) in Europe, while we did not find it to be effective with prairie voles (*Microtus ochrogaster*) in North America (Witmer et al. 2000). Of course, regional difference can also exist in how the same species of rodent responds to an odor or a toxicant.

We also tested anthraquinone which is a registered bird repellent. It is being looked at as a potential addition to rodenticides to reduce the consumption of rodenticide baits by non-target birds (Cowan et al. 2015). However, for rats, it acted as a rodent repellent even at very low concentrations (Cowan et al. 2015). In our study, however, it did not repel gophers even at a concentration of 25%.

In conclusion, it appears that the quest for an effective gopher repellent will continue to elude researchers. Other researchers have noted that potential repellents that work for some rodent species may not work for other rodent species and that ones that work for one gender may not be very effective for the other gender (Hansen et al. 2015, 2016). In our previous trials to identify effective gopher repellents, it was only predator odors that showed the most potential promise as repellents (Witmer et al. 1997). In their review, Lindgen and others (1997) also noted the potential for predator odors as repellent for various rodent species. However, in the current trials, even potential repellents that smelled like predator odors (sulfur-containing materials such as the Protect-T product) did not repel gophers. As suggested by Baldwin and others (2013), additional research and development of effective methods will be necessary to reduce rodent damage to agriculture production.

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Table 1. Carrot consumption after one day and two days by treatment groups and control groups of pocket gophers.

Group	Animal ID	Carrot Weight Day 0 (g)	Date Carrots Given	Carrot Weight Day 1 (g)	Amout Eaten Day 1 (g)	Percent Eaten Day 1	Carrot Weight Day 2 (g)	Amount Eaten Day 2 (g)	Percent Eaten Day 2	Total Amount Eaten (g)	Ave. (S.D.) Amount Eaten (g)	Total Percent Eaten	Ave. (S.D.) Percent Eaten (g)
UND 5%	OB36F	10.16	11/5/14	4.66	5.50	54.13	1.11	3.55	34.94	9.05	9.67 (0.80)	89.07	96.36 (6.31)
	OB39F	9.39	11/5/14	0.00	9.39	100.00	0.00	0.00	0.00	9.39		100.00	
	OB53M	10.57	11/5/14	1.63	8.94	84.58	0.00	1.63	15.42	10.57		100.00	
PUL 5%	OD21F	10.36	11/5/14	0.00	10.36	100.00	0.00	0.00	0.00	10.36	10.10 (1.09)	100.00	91.22 (11.91)
	OB23M	11.46	11/5/14	8.82	2.64	23.04	2.56	6.26	54.62	8.90		77.66	
	OB40F	11.50	11/5/14	3.55	7.95	69.13	0.46	3.09	26.87	11.04		96.00	
PEP 5%	OB19F	11.72	11/5/14	0.00	11.72	100.00	0.00	0.00	0.00	11.72	10.51 (1.07)	100.00	100.00 (0.00)
	OB21F	10.14	11/5/14	2.46	7.68	75.74	0.00	2.46	24.26	10.14		100.00	
	OB29M	9.68	11/5/14	0.00	9.68	100.00	0.00	0.00	0.00	9.68		100.00	
ANT 6%	OB12F	8.70	11/6/14	0.00	8.70	100.00	0.00	0.00	0.00	8.70	8.95 (0.43)	100.00	100.00 (0.00)
	OB33F	9.45	11/6/14	0.00	9.45	100.00	0.00	0.00	0.00	9.45		100.00	
	OB48M	8.71	11/6/14	0.00	8.71	100.00	0.00	0.00	0.00	8.71		100.00	
CIN 5%	OB11F	8.62	11/5/14	0.00	8.62	100.00	0.00	0.00	0.00	8.62	8.60 (0.66)	100.00	100.00 (0.00)
	OB16F	7.93	11/5/14	0.00	7.93	100.00	0.00	0.00	0.00	7.93		100.00	
	OD36AM	9.25	11/5/14	0.00	9.25	100.00	0.00	0.00	0.00	9.25		100.00	
MET 5%	OB18F	8.46	11/5/14	6.10	2.36	27.90	0.00	6.10	72.10	8.46	8.77 (0.50)	100.00	100.00 (0.00)
	OB20M	8.51	11/5/14	3.00	5.51	64.75	0.00	3.00	35.25	8.51		100.00	
	OB22M	9.35	11/5/14	0.00	9.35	100.00	0.00	0.00	0.00	9.35		100.00	
CON	OD28M	11.42	11/4/14	0.00	11.42	100.00	0.00	0.00	0.00	11.42	11.85 (0.56)	100.00	100.00 (0.00)
	OD33F	11.66	11/4/14	3.05	8.61	73.84	0.00	3.05	26.16	11.66		100.00	
	OB49F	12.48	11/4/14	5.47	7.01	56.17	0.00	5.47	43.83	12.48		100.00	
BER 5%	OB05F	12.82	11/5/14	0.40	12.42	96.88	0.00	0.40	3.12	12.82	11.85 (0.85)	100.00	100.00 (0.00)
	OB17M	11.48	11/5/14	0.00	11.48	100.00	0.00	0.00	0.00	11.48		100.00	
	OB35F	11.24	11/5/14	0.00	11.24	100.00	0.00	0.00	0.00	11.24		100.00	
UND	OB36F	18.57	11/18/14	11.42	7.15	38.50	7.69	3.73	20.09	10.88	12.40	58.59	80.35

10%	OB39F	15.32	11/18/14	4.55	10.77	70.30	0.00	4.55	29.70	15.32	(2.53)	100.00	(20.79)
	OB53M	13.34	11/18/14	6.44	6.90	51.72	2.34	4.10	30.73	11.00		82.46	
PUL 10%	OD21F	12.70	11/18/14	2.74	9.96	78.43	0.00	2.74	21.57	12.70	13.67 (1.30)	100.00	100.00 (0.00)
	OB23M	13.17	11/18/14	5.14	8.03	60.97	0.00	5.14	39.03	13.17		100.00	
	OB40F	15.15	11/18/14	6.72	8.43	55.64	0.00	6.72	44.36	15.15		100.00	
PEP 10%	OB19F	13.14	11/18/14	0.52	12.62	96.04	0.00	0.52	3.96	13.14	13.05 (0.45)	100.00	92.65 (12.72)
	OB21F	16.11	11/18/14	10.51	5.60	34.76	3.55	6.96	43.20	12.56		77.96	
	OB29M	13.45	11/18/14	2.68	10.77	80.07	0.00	2.68	19.93	13.45		100.00	
ANT 12%	OB12F	11.99	11/18/14	0.00	11.99	100.00	0.00	0.00	0.00	11.99	13.78 (2.63)	100.00	100.00 (0.00)
	OB33F	16.80	11/18/14	2.23	14.57	86.73	0.00	2.23	13.27	16.80		100.00	
	OB48M	12.54	11/18/14	3.64	8.90	70.97	0.00	3.64	29.03	12.54		100.00	
CIN 10%	OB11F	14.83	11/18/14	0.00	14.83	100.00	0.00	0.00	0.00	14.83	15.52 (1.84)	100.00	100.00 (0.00)
	OB16F	17.60	11/18/14	2.65	14.95	84.94	0.00	2.65	15.06	17.60		100.00	
	OD36AM	14.12	11/18/14	0.80	13.32	94.33	0.00	0.80	5.67	14.12		100.00	
MET 10%	OB18F	14.27	11/18/14	3.19	11.08	77.65	0.00	3.19	22.35	14.27	13.61 (1.15)	100.00	97.99 (3.49)
	OB20M	14.29	11/18/14	0.00	14.29	100.00	0.00	0.00	0.00	14.29		100.00	
	OB22M	13.07	11/18/14	1.25	11.82	90.44	0.79	0.46	3.52	12.28		93.96	
CON	OD28M	14.47	11/18/14	0.00	14.47	100.00	0.00	0.00	0.00	14.47	13.98 (0.66)	100.00	100.00 (0.00)
	OD33F	13.23	11/18/14	1.61	11.62	87.83	0.00	1.61	12.17	13.23		100.00	
	OB49F	14.24	11/18/14	5.10	9.14	64.19	0.00	5.10	35.81	14.24		100.00	
BER 10%	OB05F	14.59	11/18/14	0.00	14.59	100.00	0.00	0.00	0.00	14.59	13.95 (0.87)	100.00	100.00 (0.00)
	OB17M	14.29	11/18/14	0.00	14.29	100.00	0.00	0.00	0.00	14.29		100.00	
	OB35F	12.96	11/18/14	0.00	12.96	100.00	0.00	0.00	0.00	12.96		100.00	
Pro .5%	OD01M	9.44	11/24/14	1.34	8.10	85.81	0.00	1.34	14.19	9.44	10.19 (1.02)	100.00	100.00 (0.00)
	OD21AF	8.95	11/24/14	0.00	8.95	100.00	0.00	0.00	0.00	8.95		100.00	
	OD28M	10.30	11/24/14	0.00	10.30	100.00	0.00	0.00	0.00	10.30		100.00	
	OD33F	10.76	11/24/14	4.52	6.24	57.99	0.00	4.52	42.01	10.76		100.00	
	OB49F	11.51	11/24/14	3.82	7.69	66.81	0.00	3.82	33.19	11.51		100.00	
UND 20%	OV2M	16.2	2/2/15	0.0	16.2	100.0	0.0	0.0	0.0	16.20	12.83 (3.01)	100.00	100.00 (0.00)
	OV22M	10.4	2/2/15	0.0	10.4	100.0	0.0	0.0	0.0	10.40		100.00	

	OV28F	11.9	2/2/15	0.0	11.9	100.0	0.0	0.0	0.0	11.90		100.00	
PUL 20%	OV12M	17.4	2/2/15	0.0	17.4	100.0	0.0	0.0	0.0	17.40	15.67 (1.50)	100.00	100.00 (0.00)
	OV18M	14.9	2/2/15	4.1	10.8	72.5	0.0	4.1	27.5	14.90		100.00	
	OV21F	14.7	2/2/15	9.3	5.4	36.7	3.0	9.3	63.3	14.70		100.00	
Pro 1%	OV6M	11.4	2/2/15	0.0	11.4	100.0	0.0	0.0	0.0	11.40	10.67 (1.91)	100.00	88.98 (19.09)
	OV10M	12.7	2/2/15	4.2	8.5	66.9	0.0	0.0	0.0	8.50		66.93	
	OV17F	12.1	2/2/15	0.0	12.1	100.0	0.0	0.0	0.0	12.10		100.00	
UBP 10%/10%	OV8M	7.9	2/2/15	0.0	7.9	100.0	0.0	0.0	0.0	7.90	9.33 (1.63)	100.00	100.00 (0.00)
	OV15M	9.0	2/2/15	0.0	9.0	100.0	0.0	0.0	0.0	9.00		100.00	
	OV16M	11.1	2/2/15	1.5	9.6	86.5	0.0	1.5	13.5	11.10		100.00	
UBPMA 10%/ea	OV4M	13.3	2/2/15	0.0	13.3	100.0	0.0	0.0	0.0	13.30	11.77 (1.39)	100.00	100.00 (0.00)
	OV13M	11.4	2/2/15	0.0	11.4	100.0	0.0	0.0	0.0	11.40		100.00	
	OV30F	10.6	2/2/15	1.5	9.1	85.8	0.0	1.5	14.2	10.60		100.00	
CON	OV9M	11.4	2/2/15	0.0	11.4	100.0	0.0	0.0	0.0	11.40	12.53 (3.25)	100.00	100.00 (0.00)
	OV14M	16.2	2/2/15	3.1	13.1	80.9	0.0	3.1	19.1	16.20		100.00	
	OV31F	10.0	2/2/15	0.0	10.0	100.0	0.0	0.0	0.0	10.00		100.00	
AVI 50%	OV03M	13.0	2/23/15	6.8	6.2	47.7	5.0	1.8	13.8	8.0	10.43 (2.40)	61.5	86.67 (21.78)
	OV15M	10.5	2/23/15	0.0	10.5	100.0	0.0	0.0	0.0	10.5		100.0	
	OV24F	13.0	2/23/15	5.9	7.1	54.6	0.2	5.7	43.8	12.8		98.5	
ANT 25%	OV01F	8.6	2/23/15	4.7	3.9	45.3	0.0	4.7	54.7	8.6	10.33 (1.51)	100.0	100.00 (0.00)
	OV11M	11.0	2/23/15	0.0	11.0	100.0	0.0	0.0	0.0	11.0		100.0	
	OV22M	11.4	2/23/15	0.0	11.4	100.0	0.0	0.0	0.0	11.4		100.0	
CON	OV20F	12.9	2/23/15	3.3	9.6	74.4	0.0	3.3	25.6	12.9	10.30 (2.25)	100.0	98.26 (3.01)
	OV27M	8.9	2/23/15	0.0	8.9	100.0	0.0	0.0	0.0	8.9		100.0	
	OV31F	9.6	2/23/15	2.1	7.5	78.1	0.5	1.6	16.7	9.1		94.8	
Deer Off	OV15M	7.74	4/15/15	0.00	7.74	100.00	0.00	0.00	0.00	7.74	7.83 (0.17)	100.00	100.00 (0.00)
	OV20F	7.73	4/15/15	0.00	7.73	100.00	0.00	0.00	0.00	7.73		100.00	
	OV31F	8.03	4/15/15	0.00	8.03	100.00	0.00	0.00	0.00	8.03		100.00	
CON	OV11M	10.39	4/15/15	0.00	10.39	100.00	0.00	0.00	0.00	10.39	8.87 (1.40)	100.00	100.00 (0.00)
	OV25F	7.62	4/15/15	0.00	7.62	100.00	0.00	0.00	0.00	7.62		100.00	

	OV30F	8.60	4/15/15	0.00	8.60	100.00	0.00	0.00	0.00	8.60		100.00	

Abbreviations: UND=2-undecanone; PUL=Pulegone; PEP=Black pepper oil; ANT=Anthraquinone; CIN=Cinnamamide; MET=Methyl anthranilate; CON=Control (mineral oil only); BER=Bergamot oil; Pro=Protect-T; UND=2-undecanone; PUL=Pulegone; Prot-T=Protect-T (undiluted); UBP=Undecanone (10%) and black pepper oil (10%); UBPMA=Undecanone (10%) and black pepper oil (10%) and methyl anthranilate (10%); AVI=Avipel (undiluted from Scott Werner [50%]); ANT=Anthanilate (25% in mineral oil); Deer Off=undiluted concentrate

Table 2. Amount of wood block removed by gopher chewing after 3 days by treatment groups and control group.

Group	Animal ID	Initial Block Weight(g)	Date Block Given	Final Block Weight(g)	Date Block Removed	Total Amount Chewed (g)	Ave. (S.D.) Amount Chewed (g)	Total Percent Chewed	Ave. (S.D.) Percent Chewed
UND 10%	OV2M	16.9	1/27/2015	15.7	1/30/2015	1.20	0.57 (0.57)	7.10	3.31 (3.39)
	OV22M	17.7	1/27/2015	17.3	1/30/2015	0.40		2.26	
	OV28F	17.2	1/27/2015	17.1	1/30/2015	0.10		0.58	
PUL 10%	OV12M	16.5	1/27/2015	16.2	1/30/2015	0.30	0.27 (0.15)	1.82	1.59 (0.91)
	OV18M	16.9	1/27/2015	16.8	1/30/2015	0.10		0.59	
	OV21F	16.9	1/27/2015	16.5	1/30/2015	0.40		2.37	
Prot-T	OV6M	19.2	1/27/2015	16.3	1/30/2015	2.90	2.63 (0.38)	15.10	13.21 (2.24)
	OV10M	20.5	1/27/2015	18.3	1/30/2015	2.20		10.73	
	OV17F	20.3	1/27/2015	17.5	1/30/2015	2.80		13.79	
UBP	OV8M	17.4	1/27/2015	17.0	1/30/2015	0.40	3.13 (4.65)	2.30	17.90 (26.56)
	OV15M	17.5	1/27/2015	9.0	1/30/2015	8.50		48.57	
	OV16F	17.6	1/27/2015	17.1	1/30/2015	0.50		2.84	
UBPMA	OV4M	16.3	1/27/2015	16.0	1/30/2015	0.30	0.80 (0.78)	1.84	4.69 (4.41)
	OV13M	17.4	1/27/2015	15.7	1/30/2015	1.70		9.77	
	OV30F	16.2	1/27/2015	15.8	1/30/2015	0.40		2.47	
CON	OV9M	17.2	1/27/2015	16.6	1/30/2015	0.60	2.87 (4.01)	3.49	15.97 (22.06)
	OV14M	16.8	1/27/2015	16.3	1/30/2015	0.50		2.98	
	OV31F	18.1	1/27/2015	10.6	1/30/2015	7.50		41.44	

Abbreviations and concentrations: UND=2-undecanone 10% (= methyl nonyl ketone); PUL=Pulegone 10%; Prot-T=Protect-T (undiluted; <1% propriety active ingredients); UBP=Undecanone (10%) and black pepper oil (10%); UBPMA=Undecanone (10%) and black pepper oil (10%) and methyl anthranilate (10%); CON=Control (mineral oil only)