‘CR9’: A New Highly Aromatic Catnip *Nepeta cataria* L. Cultivar Rich in *Z,E*-Nepetalactone

William Reichert, H. Chung Park, H. Rodolfo Juliani,
and James E. Simon¹

*New Use Agriculture and Natural Plant Products Program, Department of
Plant Biology and Pathology, Rutgers University, New Brunswick, NJ 08901*

Additional index words. cats, *Z,E*-nepetalactone, essential oil, insect repellent, mosquitoes, malaria

Catnip (*Nepeta cataria*, Fam. Lamiaceae), an aromatic herb from southwestern Asia, is best known for causing a euphoric effect on domestic cats and other members of the feline family due to the volatile compound nepetalactone contained in the essential oil of the plant (Jamzad et al., 2003; McElvain et al., 1941; Waller et al., 1969). The aromatic volatiles of catnip are produced in the glandular trichomes on the leaf epidermis (Moon et al., 2009). Due to the morphological nature of the bilabiate bisexual flowers, this plant can self-pollinate and also has the ability to outcross (Cläßen et al., 2003). Current production methods use seeds and transplants from undomesticated populations. While normally cultivated for the pet toy industry as a safe attractant to cats and for ornamental applications, recent research has shown that essential oils from catnip are an efficient insect repellent and are at least comparable to repelling insects than the industry standard repellent DEET with far less toxicity (Bernier et al., 2005; Feaster et al., 2009; Peterson et al., 2002; Schultz et al., 2006; Waller et al., 1969).

Catnip's volatile oil effectively repels mosquitoes, including the females that carry the plasmodium that causes malaria and those that transmit yellow fever, filariasis, the West Nile virus and encephalitis for a total of six different mosquito species repelled (Abdelkrim and Mehlhorn, 2006; Bernier et al., 2005; Birkett et al., 2011; Chauhan et al., 2012). In one study, 41 different plant species were tested for repellency toward three species of mosquitoes that carry pathogens and *N. cataria* was one of the top five plants whose oil exhibited repellency

(Abdelkrim and Mehlhorn, 2006). The *Z,E*-isomer can also be hydrogenated to form dihydronepetalactone 2 that is as effective at repelling two species of mosquitos as well as DEET and offers complete protection for up to 5 h in experiments involving human subjects (Feaster et al., 2009). The *Z,E*-isomer has shown significant repellency toward house and stable flies as well as being shown that catnip-derived nepetalactones are an oviposition repellent (Schultz et al., 2006; Zhu et al., 2009, 2010, 2012). The peach-potato aphid is also repelled by nepetalactones suggesting that *N. cataria* could be evaluated as an organic repellent for peach orchards and potato fields (Fernandez-Grandon et al., 2013). In addition, both the American and German cockroach, which harbor disease causing organisms, were repelled by the nepetalactones present in *N. cataria* and showed better repellency than DEET (Peterson et al., 2002; Schultz et al., 2004, 2006). Common brown ticks and the deer tick that harbor the bacterium responsible for Lyme disease are repelled by the nepetalactones and dihydronepetalactones in *N. cataria* (Birkett et al., 2011; Feaster et al., 2009). Three species of subterranean termites that chew away at houses and other various wood-based structures causing significant financial loss were also repelled by the nepetalactones found in catnip oil (Chauhan and Raina, 2006; Haenke, 2003; Peterson and Ems-Wilson, 2003). The *Z,E*-nepetalactone isomer was also efficient in repelling many common house dust mite species and poultry mites (Birkett et al., 2011; Khan et al., 2012). In a body contact assay involving harvester ants, mortality was achieved faster with the *Z,E*-isomer than the other nepetalactones in catnip oil (Gkinis et al., 2003). A commercial repellent has been patented that uses the nepetalactones derived from *N. cataria* (Wagner, 2004). Pilot programs have been implemented to assess the ability to commercially produce the nepetalactones from *N. cataria* yet commercial viability of using catnip oil has been limited by the high cost of the essential oil due to the physiological characteristics of the currently offered catnip plants (Birkett and Pickett, 2003; Park et al., 2007).

Catnip populations still remain largely undomesticated. Little breeding has been undertaken to improve catnip's horticultural

traits. Relative to other members of the Lamiaceae family, catnip plants are susceptible to diseases and environmental stress including poor winter survival in northern temperate zones. Tolerant plants can be perennials but in commercially grown fields they are currently cultivated as annuals. Commercial fields from clonal transplants are more expensive as the labor cost is greater and the process is more difficult as the plants die off, produce less biomass and exhibit phenotypical architecture that does not lend itself to efficient mechanization. They also produce lower essential oil yields in comparison with peppermint and spearmint plants that produce copious amounts of aromatic oils that can be commercially harvested mechanically. In addition to lower essential oil yields, the plants have not been bred to increase *Z,E*-nepetalactone, the key bioactive constituent found in the volatile aromatic oil. These factors have made the commercialization of catnip as a source for aboveground biomass, essential oils, and the isolated compound for new insect repellent products most challenging (Park et al., 2007). These factors also make it difficult to effectively cultivate mechanically and commercialize to obtain the desired bioactive compound in the volatile oil (Park et al., 2007).

CR9 is the first cultivar of *N. cataria* in North America developed specifically for commercial agricultural production with a more upright growth habit and higher biomass, essential oil, and *Z,E*-nepetalactone yield (as a function of the relative percentage of the total essential oil yield). Essential oil from current catnip contains many aromatic volatile compounds including nepetalactone (Baser et al., 2000). This cultivar was developed and is distinct from other commercially available sources because it produces a uniform seeded offspring in the desired characteristics. The selfed progeny of ‘CR9’ produces higher amounts of biomass and essential oil yields, and the essential oil is richer in the production of the bioactive isomer *Z,E*-nepetalactone in these populations. The progeny of ‘CR9’ provides a superior type of catnip plant for commercial field production, for dried catnip or for the distilled aromatic essential oils that has multiple applications including the pet toy and insect repellent industries.

Origin

‘CR9’ was developed after six different randomized complete block growth trials by selecting the best field performing plants that grew the most upright, survived the winters in New Jersey and produced the highest aboveground biomass, essential oil, and *Z,E*-nepetalactone yields (Table 1). In 2001, the U.S. Department of Agriculture (USDA) *N. cataria* germplasm was comparatively grown at the Rutgers Clifford E. & Melda Snyder Research Farm, in Pittstown, NJ, with a wide range of commercial catnip varieties in a seeded field trial. For two growing seasons, this population of plants had many individual plants that were off types, exhibited

Received for publication 29 Sept. 2015. Accepted for publication 7 Mar. 2016.

We thank the New Jersey Farm Bureau and the New Jersey Agricultural Experiment Station for their support. We also thank Ed Dager, Mark Peacos, Pierre Tannous, and Qingli Wu for their assistance in the lab and/or field with this research project and Daniella Simon, Walter Reichert, and Barbara Reichert for the encouragement to develop a super catnip line.

Chemical Name: cyclopenta(c)pyran-1(4*aH*)-one, 5,6,7,7a-tetrahydro-4,7-dimethyl-, [4*aS*-(4*aα*,7*α*,7*aα*)] (*Z,E*-nepetalactone)

¹Corresponding author. E-mail: jesimon123@gmail.com.

Table 1. Genealogy of the new catnip cultivar CR9 (*Nepeta cataria*).

2001	Original seeded field establishment for evaluation of the <i>N. cataria</i> U.S. Department of Agriculture (USDA) germplasm and commercial lines including the USDA germplasm PI no. W6 17691.
	Evaluation of desired morphological characteristics and the rouging out of poor performing plants was performed.
2002	Plants remaining in 2002 that successfully overwintered from 2001 and exhibited desired morphological characteristics formed the breeding lines (C244, C245, C246, C47, C248, C249, and G1) and were allowed to outcross.
2005	The outcrossed seeds from lines (C244, C245, C246, C47, C248, C249, and G1) were sown in a field trial and evaluated for desired phenotypic characteristics. Poor performing plants were rouged out.
2006	Plants remaining from the 2005 field trials and exhibiting desired phenotypic characteristics were selected forming the breeding line (CR). (CR) breeding lines were allowed to self-pollinate in a research greenhouse.
2007	The selfed (CR) lines were sown in a field trial in which individual plants were identified for desired phenotypic characteristics with emphasis on essential oils.
2008	Selections of plants (CR1, CR2, CR3, CR4, CR5, CR6, CR7, CR8, and CR9) from the CR breeding line were made after the 2007 winter with emphasis on essential oils.
2010	Clonal evaluation of advanced breeding lines (CR1, CR2, CR3, CR4, CR5, CR6, and CR9) for desired morphological characteristics and essential oils was conducted.
2011	Clonal evaluation of advanced breeding lines (CR1, CR2, CR3, CR4, CR5, CR6, and CR9) for desired morphological characteristics and essential oils was conducted. Breeding lines were allowed to self-pollinate in a research greenhouse.
2013	Final seeded evaluation of the selfed advanced breeding line 'CR9' and the five commercial lines for comparison. Selection of (CR9) for the new catnip cultivar <i>N. cataria</i> CR9

Table 2. Morphological and essential oil characteristics of the new catnip cultivar CR9 compared with commercial catnip varieties over two harvests, 2013.^z

2013 harvest one	Morphological characteristics					Essential oil analysis	
	Plant ht (cm)	Plant spread (cm)	Leaf length (cm)	Leaf width (cm)	Dry wt per plant (g)	Oil yield per plant (g)	Z,E-nepetalactone yield per plant (g)
CR9	65.9 A ^y	92.1 BC	6.0 A	4.8 A	158.0 A	1.54 A	1.34 A
JON	56.5 B	98.0 AB	4.7 B	3.5 B	115.0 BC	1.05 B	0.74 B
RICH	55.4 B	100.9 A	4.8 B	3.6 B	113.3 BC	0.90 B	0.73 B
STOKES	53.3 BC	94.0 ABC	4.9 B	3.7 B	127.7 B	1.21 AB	0.22 C
TERR	55.9 B	101.3 A	4.4 BC	3.3 B	112.3 BC	1.16 AB	0.21 C
CFM	50.4 C	87.5 C	4.0 C	3.4 B	88.0 C	0.46 C	0.06 C

2013 harvest two	Morphological characteristics					Essential oil analysis	
	Plant ht (cm)	Plant spread (cm)	Leaf length (cm)	Leaf width (cm)	Dry wt per plant (g)	Oil yield per plant (g)	Z,E-nepetalactone yield per plant (g)
CR9	51.1 A	82.5 AB	5.8 A	4.1 A	177.0 A	1.38 A	0.35 A
CFM	46.3 B	89.7 A	5.7 A	3.7 A	136.0 AB	0.84 B	0.21 B
STOKES	43.3 BC	80.7 AB	5.7 A	3.7 A	115.7 AB	0.73 BC	0.19 BC
RICH	44.3 B	83.1 AB	5.5 A	3.7 A	157.3 AB	0.63 BC	0.16 BC
TERR	43.3 BC	77.5 B	6.0 A	3.9 A	101.7 B	0.50 BC	0.13 BC
JON	39.4 C	79.7 AB	5.8 A	3.9 A	125.0 AB	0.42 C	0.11 C

^zCR9 = Rutgers new cultivar release; CFM = Ferry Morse Seeds, Norton, MA; JON = Johnny's Selected Seeds, Albion, ME; RICH = Richters Herbs, Goodwood, ON, Canada; STOKES = Stokes Seeds, Buffalo, NY; TERR = Territorial Seed Company, Cottage Grove, OR.

^yValues within columns followed by different letters are significantly different according to Duncan's test at $P \leq 0.05$.

Fig. 1. Single plant of catnip cultivar CR9 (*Nepeta cataria*) with insect pollinators (below the yellow arrows).

poor performance and/or winter injury removed from the study. In 2002, the remaining plants from the best performing USDA line PI no. W6 17691 were allowed to outcross by wind and bees, the seed was collected from the remaining individual plants and the new advanced breeding line was formed. In 2005, these seeds were sown in a field trial at the Rutgers Fruit and Ornamental Research Extension Center in Cream Ridge, NJ, to identify lines with the desired phenotypic characteristics and to evaluate their uniformity. Only the most promising plants were left in the field, all others were removed. In 2006 after the plants were subjected to the winter season and assessed for winter survival, selections were made on this field with respect to biomass and winter survival by taking cuttings of the

individual plants and allowing them to self-pollinate in a research greenhouse. In 2007, those selfed seeds were planted in another 2-year evaluation at the Rutgers Clifford E. & Melda Snyder Research Farm, Pittstown, NJ. Selections took place on the 2nd year after the plants were subjected to the winter season; however, plant selections were largely based on total essential oil production (e.g., yield/plant) and Z,E-nepetalactone concentration. The selections from 2008 were then clonally evaluated for two additional years in 2010 and 2011 at the same research farm to ensure minimal environmental influence on the variation of essential oil yields and nepetalactone concentration. Those clones were then selfed and the seed used in the next growth trial in 2013.

Fig. 2. Gas chromatogram of the essential oil from catnip cultivar CR9 (*Nepeta cataria*) illustrating the peak of Z,E-nepetalactone.

Fig. 3. Mass spectra of Z,E-nepetalactone, the major compound found in the essential oil of catnip cultivar CR9 (*Nepeta cataria*).

In 2013, the clones demonstrating uniform production of essential oil yields and nepetalactone concentration had their selfed progeny planted in a final seeded field evaluation that year at the New Jersey Agricultural Experiment Station Clifford E. & Melda Snyder Research Farm, Pittstown, NJ. The progeny of 'CR9' was field grown and compared with commercial seed companies offering catnip seeds (Johnny's Selected Seeds, Albion, ME; Ferry Morse, Norton, MA; Stokes, Buffalo, NY; Territorial Seed Company, Cottage Grove, OR; Richters Herbs, Goodwood, ON, Canada). The land was cultivated by disc plowing, raised beds were then mechanically prepared followed by the placement of drip irrigation and plastic mulch. The land was fertilized at 900 lbs/acre of

15-15-15 and was irrigated through drip irrigation as needed and described (Park et al., 2007). The experimental design for 2013 was a randomized complete block design with 10 plants in each of the six lines having their morphological characteristics recorded for each of the three replications. The plants were spaced 61 cm apart within the rows and the rows were spaced 274 cm apart. Once the plants were in full flower, morphological characteristics were recorded, the plants were cut back to the ground level after 10 weeks and the entire plot was bulk harvested and dried on site at 37 °C using a walk-in forced air commercial Powell Tobacco dryer (MarCo Manufacturing Company LLC, Bennettsville, SC) converted to the drying of herbs and botanicals. Plant

height, plant width, leaf length, leaf width, and dry weights were recorded. Plant height was measured from the soil level to the flowers down the center of the plant. Plant width was determined by measuring the diameter of the plant. Leaf length was the measurement from the tip of the leaf to the beginning of the petiole on the side that connects to the leaf. The width of the leaf was measured at the basal portion of the leaf at the largest diameter. Dry weights were determined by recording the weight after plants had lost all the water at the set unified temperature at 37 °C. The plants in the field were allowed to grow again to maturity, when they were again bulk harvested as described above and dried on site at 37 °C. Essential oil yields were determined by the

hydro distillation of all of the aboveground biomass of the plant using a Clevenger-type distillation unit with 100 g of dry plant matter. The yields were calculated as percent of dry mass (gram essential oil/100 g aboveground biomass). Essential oil analysis was performed by quantitatively comparing the samples using a flame ionization detector and qualitatively by identifying the chemical constituents of the oil with mass spectrometry (Juliani et al., 2008).

Description

The progeny of the CR9 cultivar of *N. cataria* have opposite triangular ovate leaves that have crenate edges. All of the leaves are dark to light green. These plants are bushy and flower within 90 d. The white bilabiate flowers are grown on terminal inflorescences in whorls. 'CR9' plants were the tallest and had the largest leaves. Once cut back and allowed to regrow, 'CR9' plants remained the tallest but the leaf dimensions now resembled the commercial lines in the same study (Table 2). In central New Jersey's growing zone six (40.559340, -74.961282), this plant can be harvested twice in a growing season for biomass, essential oils, and for *Z,E*-nepetalactone. 'CR9' can also be kept from flowering by continually pruning it. The plants serve as an excellent source for pollinators. Bees, butterflies, and many other insects frequently visited all the catnips including the progeny of 'CR9' plants during the entire flowering period (Fig. 1). Chemical characterization of the essential oil of these plants using gas chromatography-mass spectrometry with alkane standards confirmed the presence of *Z,E*-nepetalactone (Figs. 2 and 3) (Adams, 2007).

Performance

'CR9' performed better than each of the commercial seed companies to which it was compared. 'CR9' has a mean dry weight per plant of 158.0 g/plant on the first harvest and 177.0 g on the second harvest for a total of 335 g/year with a 33% improvement over the closest commercial line. The essential oil yield per plant is 1.54 g/plant on the first harvest and 1.38 g/plant on the second harvest for a total of 2.92 g/year with a 54% improvement over the closest commercial line. *Z,E*-nepetalactone yield was 1.34 g/plant on the first harvest and 0.35 g on the second harvest for a total of 1.7 g/year with a 77% improvement over the closest commercial line. On the first harvest the concentration of *Z,E*-nepetalactone was 87% and 25% on the second harvest. All catnip lines evaluated had their concentration of *Z,E*-nepetalactone decrease to lower levels on the second harvest. This new cultivar survived winter conditions and exhibited the least winter injury and dieback compared with the commercial catnips that were evaluated. As a garden herb, 'CR9's progeny can live for many additional years on the landscape and could be considered aesthetically attractive with light green soft leaves and a highly pleasant spice-like aroma. This new cultivar's population lends itself more to mechanical harvesting as is

required for larger-scale essential oil production and was developed for this purpose. Because of the increased essential oil the population makes, the commercialization of this catnip cultivar as an essential oil crop is more realistic than prior and current catnip lines. Producers of catnip essential oils and extracts designed for the insect repellent industry could increase their income significantly by planting this new cultivar given it was developed as an improved source of essential oil of catnip for larger growers with steam distillation facilities.

Availability

This new cultivar developed by the New Jersey Agricultural Experiment Station was licensed exclusively to Ball Horticultural Company, 622 Town Road, West Chicago, IL 60185 for distribution.

Literature Cited

- Abdelkrim, A. and H. Mehlhorn. 2006. Repellency effect of forty-one essential oils against *Aedes*, *Anopheles* and *Culex* mosquitoes. *Parasitol. Res.* 99:478-490.
- Adams, R. 2007. Identification of essential oil components by gas chromatography/mass spectrometry. 4th ed. Allured Pub Corp., Carol Stream, IL.
- Baser, K.H.C., N. Kirimer, M. Kurkcuglu, and B. Demirci. 2000. Essential oils of *Nepeta* species growing in Turkey. *Chem. Nat. Compd.* 36: 356-359.
- Bernier, U.R., K.D. Furman, D.L. Kline, S.A. Allan, and D.R. Barnard. 2005. Comparison of contact and spatial repellency of catnip oil and *N,N*-Diethyl-3-methylbenzamide (Deet) against mosquitoes. *J. Med. Entomol.* 42:306-311.
- Birkett, M.A., A. Hassalinali, S. Hoglund, J. Pettersson, and J.A. Pickett. 2011. Repellent activity of catmint, *Nepeta cataria*, and iridoid nepetalactone isomers against Afro-tropical mosquitoes, ixodid ticks and red poultry mites. *Phytochemistry* 72:109-114.
- Birkett, M.A. and J.A. Pickett. 2003. Aphid sex pheromones: From discovery to commercial production. *Phytochemistry* 62:651-656.
- Chauhan, K.R. and A.K. Raina. 2006. Effect of catnip oils and its major components on the Formosan subterranean termite *Coptotermes formosanus*. *Biopestic. Int.* 2:137-143.
- Chauhan, K.R., J.R. Aldrich, P.W. McCardle, G.B. White, and R.E. Webb. 2012. A field bioassay to evaluate potential spatial repellents against natural mosquito populations. *J. Amer. Mosquito Control Assn.* 28:301-306.
- Cläuien, B.R., P. Wester, and E. Tweraser. 2003. The staminal lever mechanism in *Salvia* L. (Lamiaceae): A review. *Plant Biol.* 5:33-41.
- Feaster, J.E., M.A. Scialdone, R.G. Todd, Y.I. Gonzalez, J.P. Foster, and D.L. Hallahan. 2009. Dihydronepetalactones deter feeding activity by mosquitoes, stable flies, and deer ticks. *J. Med. Entomol.* 46:832-840.
- Fernandez-Grandon, G.M., C.M. Woodcock, and G.M. Poppy. 2013. Do asexual morphs of the peach-potato aphid, *Myzus persicae*, utilize the aphid sex pheromone? Behavioural and electrophysiological responses of *M. persicae* virginoparae to (4aS,7S,7aR)-nepetalactone and its effect on aphid performance. *Bull. Entomol. Res.* 103:466-472.
- Gkinis, G., T. Olga, D. Iliopoulou, and V. Roussis. 2003. Chemical composition and biological activity of *Nepeta parnassica* oils and isolated nepetalactones. *Z. Naturforsch. C* 58C:681-686.
- Haenke, J. 2003. Materials and methods for controlling wood boring insects. United States Patent WO2003086069.
- Jamzad, Z., M.W. Chase, M. Ingrouille, M.S.J. Simmonds, and A. Jalili. 2003. Phylogenetic relationships in *Nepeta* L. (Lamiaceae) and related genera based on ITS sequence data. *Taxon* 52:21-32.
- Juliani, H.R., J.E. Simon, C. Quanash, E. Asare, R. Akromah, D. Acquaye, J. Asante-Dartey, M.L.K. Mensah, T.C. Fleischer, R.K. Dickson, K. Annan, and A.Y. Mensah. 2008. Chemical diversity of *Lippia multiflora* essential oils from West Africa. *J. Essential Oil Res.* 20:49-55.
- Khan, M.A., I. Jones, E. Loza-Reyes, M.M. Cameron, J.A. Pickett, and M.A. Birkett. 2012. Interference in foraging behaviour of European and American house dust mites *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae* (Acari: Pyroglyphidae) by catmint, *Nepeta cataria* (Lamiaceae). *Exp. Appl. Acarol.* 57:65-74.
- McElvain, S.M., R.D. Bright, and P.R. Johnson. 1941. The constituents of the volatile oil of catnip. I. Nepetalic acid, nepetalactone and related compounds. *J. Amer. Chem. Soc.* 63:1558-1563.
- Moon, H.K., S.P. Hong, E. Smets, and S. Huysmans. 2009. Phylogenetic significance of leaf micromorphology and anatomy in the tribe Mentheae (Nepetoideae: Lamiaceae). *Bot. J. Linn. Soc.* 160:211-231.
- Park, C.H., P. Tannous, H.R. Juliani, Q.L. Wu, W.J. Sciarappa, R. VanVranken, P. Nitzsche, D. Dalponte, and J.E. Simon. 2007. Catnip as a source of essential oils, p. 311-315. In: J. Janick and A. Whipkey (eds.). *Issues in new crops and new uses*. ASHS Press, Alexandria, VA.
- Peterson, C.J. and J. Ems-Wilson. 2003. Catnip essential oil as a barrier to subterranean termites (Isoptera: Rhinotermitidae) in the laboratory. *J. Econ. Entomol.* 96:1275-1282.
- Peterson, C.J., L.T. Nemetz, L.M. Jones, and J.R. Coats. 2002. Behavioral activity of catnip (Lamiaceae) essential oil components to the German cockroach (Blattodea: Blattellidae). *J. Econ. Entomol.* 95:377-380.
- Schultz, G., C. Peterson, and J. Coats. 2006. Natural insect repellents: Activity against mosquitoes and cockroaches. *ACS Symposium Series.* 927:168-181.
- Schultz, G., E. Simbro, J. Belden, J. Zhu, and J.R. Coats. 2004. Catnip, *Nepeta cataria* (Lamiales: Lamiaceae)—A closer look: Seasonal occurrence of nepetalactone isomers and comparative repellency of three terpenoids to insects. *Environ. Entomol.* 33:1562-1569.
- Wagner, M.W. 2004. Bugnip. United States Patent 20040197362.
- Waller, G.R., G.H. Price, and E.D. Mitchell. 1969. Feline attractant, cis, trans-nepetalactone: Metabolism in the domestic cat. *Science* 164:1281-1282.
- Zhu, J.J., D.R. Berkebile, C.E. Dunlap, A. Zhang, D. Boxler, K. Tangtrakulwanich, R.W. Behle, F. Baxendale, and G. Brewer. 2012. Nepetalactones from essential oil of *Nepeta cataria* represent a stable fly feeding and oviposition repellent. *Med. Vet. Entomol.* 26:131-138.
- Zhu, J.J., C.A. Dunlap, R.W. Behle, D.R. Berkebile, and B. Wienhold. 2010. Repellency of a wax-based catnip-oil formulation against stable flies. *J. Agr. Food Chem.* 58:12320-12326.
- Zhu, J.J., X.P. Zeng, D. Berkebile, H.-J. Du, Y. Tong, and K. Qian. 2009. Efficacy and safety of catnip (*Nepeta cataria*) as a novel filth fly repellent. *Med. Vet. Entomol.* 23:209-216.