Can insecticide resistance be developed in termites?

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Defined as a heritable change in the sensitivity of a pest population, insecticide-induced resistance is reflected in repeated failure in attaining the desired control[1]. However, failure to control urban insect-pests like termites is often attributed to insecticide resistance. Treatment failures are often due to differences in toxicity, repellency, speed of intoxication and vapour pressure characteristics of termiticides[2]. Failure to correctly identify the termites, wrong selection of insecticides/formulations, faulty delivery systems and post-treatment re-infestation may add to treatment failure. The list of urban pests exhibiting resistance to insecticides is impressive (e,g. cockroach, housefly and mosquitoes), but resistance has not been demonstrated among social insects such as ants, wasps and termites[3,4], except the case of leafcutter ant in cocoa crop (www.pesticideresistance.com). Obviously, a question often arises: can insecticide resistance be developed in termites?

Eusociality provides insects with multi-tiered tolerance against natural selection pressure. The phenomenon of polyphenism (i.e. castes), bio-ecology and termite life cycle should be well understood before answering the question posed in the title of this note. In general, termite queen may live for 10–20 years, while workers and soldiers live for 2–5 years; alates are seasonal in occurrence during swarming. Such an intricate caste system in termites makes the key proximate mechanisms of resistance development hard to materialize. Caste differentiation is triggered by a complex interaction of intrinsic and extrinsic factors. Added to this, the *r–k* continuum strategies in various castes of the termite colony are advantageous for the termites[5]. Behavioural resistance limited to one generation may be possible in termites; penetration resistance (toxin absorption slowed down by cuticular barriers), metabolic resistance and altered-targetsite resistance are the other probabilities. Alongside genetic adaptation, organisms can respond to environmental challenges through adaptive phenotypic plasticity, which refers to a non-genetic shift in the average characteristics (phenotype) of a population. The recently demonstrated case of a vertebrate (wood frog) developing pesticide resistance through phenotypic plasticity in just one generation[5], implies that in termites though phenotypic plasticity is yet to be documented, it cannot be ruled out. Lack of tools of detection and cumbersome experimental needs, standard rearing and bioassay techniques, particularly for higher termites are the bottlenecks in the documentation of resistance development.

Termites harbour a gutful of symbiotic microflora (in lower termites) that helps in lignocellulose digestion. To develop successfully, a viable resistance development strategy, the enzymatic detoxification mechanism, may be accomplished by not only the termites but also by the associated gut-flora responsible for secreting such digestive enzymes. Certainly resistance development by a group of organisms simultaneously is hard to achieve. Even if it is possible, the intended mechanism is much more complicated to materialize in reality (readers may refer to Nobre and Aanen[6] for details) and delayed in higher termites (fungus-farming termites, subfamily: Macrotermitinae), as they are associated with macro-fungi in the fungal comb. In this connection, the red queen hypothesis[7] is apt to be cited. Mutualistic symbiosis plays a major role through synergy and combined capabilities; the mutualistic alliance between two or more organisms adapts to adverse conditions (like pesticide exposure) faster than individual partners of the mutualism. Thus, any favourable directional flow of resistance development in the system is abated or reversed by this adaptability.

A keen discussion into the potential factors influencing the selection of resistance to insecticides[8] vis-à-vis genetic, biological and operational factors – seems mostly skewed in favour of termites to overcome or at least delay resistance induction. Mechanisms of resistance development in termites may include antibiotic secretions, mutual grooming, removal of diseased/affected individuals from the nest, and the innate and adaptive immune responses of colony members. Termites improve their ability to resist infection successfully and significantly when they come in contact with previously immunized nestmates. This 'social transfer' of infection resistance could explain how group living enhances the survivorship of colony members, despite the increased risks of alien agents (insecticides) transmission[9]. A fifty-year research-review analysis suggests the failure of termite biological control, publication bias, and poor understanding of termite biology[10].

Nevertheless, insecticide resistance development cannot be completely overruled. Being the oldest living fossils, termites have the ability to self-protect; xenobiotic compounds may undergo biotransformation phases to transform harmful toxins to harmless residues and exit out of the body[11]. Investigation on xenobiotic pathway of *Coptotermes curvignathus* revealed that the enzymatic metabolism involved three biotransformation phases of detoxification, inclusive of cytochrome-P450, monooxygenase, glutathione S-transferase, carboxylesterase, UDP-glucuronyl tranferase and *N*-acetyltransferase. Termite-gut or endosymbiont-secreted enzymatic cascade can be the proximate resistance mechanism target. The generation turn-over of symbiotic microbes may overcome the hurdle of longer generation time of termites, facilitating favourable mutation or gene-regulation/alternation leading to insecticide resistance development.

When left unchecked, termites can devour an entire township. For example, in 1955, Sri Haragovindpur, a village in Punjab was abandoned by the villagers. A similar serious case due to termite attack was confronted by us in a desert village (Kota district, Rajasthan) that created major news headlines (*Dainik Bhaskar*, 7 May; 18 October and 28 November 2013, *The Indian Express* 14 July 2013 and 2 March 2014). The termite, *Heterotermes indicola*, was correctly identified by us. Unaware public, media and even professionals often attribute such instances to the resistance development in insects (termites). This is elusive and at best may be adjudged as resurgence of termites, rather than resistance. Moreover, this is a natural resurgence, and not an insecticide-induced one. Studies on termites metabolizing on xenobiotic substances such as lignin, plant allele chemicals and insecticides are lacking[11]. A comparative study of detoxifying enzymes (esterases and glutathione S-transferase) between worker and soldier castes of *Odontotermes obesus*, revealed possible adaptation to tolerate pesticides[12]. In termites, upregulated cytochrome P450 content, aldrin epoxidation, cytosolic esterase[13,14] and microsomal esterases[15] activity were observed on exposure to cypermethrin, chlordane, chlorpyrifos and pyrethroid. Hence concerted research endeavours are needed in this line. The fact that resistance development is not yet documented in termites[3,4], should not make us complacent. Several other life strategies exhibited by the termite colony make it hard to eliminate these tiny creatures from our farms, houses or gardens altogether[16].

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