4 / DISCUSSION

The results of this study clearly demonstrated that the FAW developed resistance for cypermethrin in both the small and large droplet deposition patterns, which were produced by XR8001vs and XR8008vs nozzles respectively. The level of development of resistance was faster and higher in the large droplet deposition pattern colony vs that in the small droplet deposition pattern colony. Our results are in agreement with[8] who reported that fall armyworm developed 9.5-fold resistance to cypermethrin in the resistance strain compared with a laboratory susceptible strain. Results[7] we found that there were insignificant differences between the total amounts of deposition on corn plants produced by XR8008vs and XR8001vs nozzles (480.54 and 421.89µg g^{-1} dry weights respectively). However, droplet sizes, number, and distribution are highly varied between these two patterns. Furthermore, Atomization results indicated that small droplet nozzle provided better coverage (20.4 L/m^2) or about three times as much as the large droplet nozzle (6.96 L/m^2). As a result, the amount of active ingredient in a given leaf area will be different between these two deposit patterns, despite using the same concentration of spray from the same tank mix. However, in the real world, deposit distribution over a plant canopy is affected by plant canopy structure.

Biological efficacy results[7] showed that larval mortality in small droplet patterns was higher than in the large droplet patterns and leaf consumption was less in the small droplet pattern than in large droplet patterns. Furthermore, feeding behavior varied between small and large droplet patterns. We also observed that feeding percentages under the small deposit patterns was less than in the large deposit patterns. In the large deposit patterns, the larvae fed more and continued feeding between the large deposits and stayed in one place producing large holes. under the small deposit patterns, the larvae moved about producing small holes on the leaf edges and under leaf surfaces[7]. Our results are in agreement with the Adams[8] results who found that ingestion of permethrin inhibited larval feeding in the more susceptible population of the diamondback moth *Plutella xylostella* (L.) larvae on leaf discs treated with individually applied, uniformly sized droplets. Consequently, the larvae will encounter a lethal dose in small deposit patterns mainly by contact and by feeding, while in large deposit patterns they will encounter sub lethal doses by feeding as well as contact, which will select for development of polygenic resistance10. Moreover, in the large deposit patterns (Figure 1B) the areas between the large deposits are not 100% chemical free i.e.: there are very small deposits between the large deposits that could be a source of a sub lethal dose. Therefore, the larval encounter process for a chemical may be different depending on application methodology. Consequently, the exact amount reaching the site of action will be different and could contribute to different LD_{50} values. This study was not designed to elucidate the various contributions to resistance by pest behavior, tolerance development or physiological resistance. Nevertheless, it is clear that the patterns of deposit resulted in deferent response in resistance of both compounds.

The route of entry could be an important factor in the development of resistance. The resistance ratio determined with Spinosad (formulated as Tracer™) in tobacco budworm *Heliothis virescens* (F) diet was 314-fold at 15 days after the start of exposure. Injection of spinosad into the larval hemocoel resulted in a 163-fold resistance ratio 15 days after injection, indicating that resistance could be explained simply by altered penetration[9]. Moreover, sun[10] found that carbaryl was inactive by topical application on house-flies but the toxicity increased 400-fold when applied by injection therefore bypassing the cuticle. Thus the low toxicity by topical application is attributed to slow penetration, which affords ample opportunity for the very active detoxication mechanisms to destroy the incoming toxicant.

The mortality of 3rd instar FAW in spinosad colonies at different selection doses determined 24 hours after topical application showed that there were insignificant differences in the LD_{50} values between treatments (Table 3). However, we found that larval mortality was higher in the small deposit patterns and feeding percentage in general was less in the small deposit patterns[7]. Generally, larvae continued feeding longer than they did in the cypermethrin treatments, which may be due to the fast action of cypermethrin (knockdown).

We hypothesize that the difference in development of resistance to cypermethrin and spinosad with small deposit patterns vs large deposit patterns is due to factors such as deposition structure, insect behavior, chemical type, and mode of action. The deposit structure has three elements of deposit size, number per area, and toxin per deposit[4]. The other important element influencing efficacy is distribution which may have an important influence on larval behavior such as movement, feeding, and avoidance. The distribution of permethrin deposits on leaf surfaces has been reported to be significantly affected the quantity of insecticide ([AI]/ cm^2) required for mortality[8]. Insect behavior could have influenced exposure in this case, resulting in less insecticide being encountered when it was distributed more unevenly.

This study is the first case of such a study of pesticide application methodologies, identifying droplet characteristics, as well as presentation, distribution phenomena in several plant structures, and biological effects including resistance from each application scenario[7]. We hypothesize there is a high probability of such a correlation with insect resistance showing the influence of deposit patterns making a difference in resistance development and confirm that chemistry and behavioral responses combined with deposition patterns may also contribute to the demise of effective pesticide mortality[7].

In summary, small droplet patterns can provide not only higher biological efficacy and has aid better crop protection and delay the onset of pest resistance. In our study, we haven't examined the enzymatic changes in each scenario which might be occurring as a result of chemical selection pressure and thus contribute to resistance. However, the impact of delivery technologies influencing deposit structure on the development of resistance needs to be studied in different canopies, with various chemicals, and should be considered in any IPM program before making pest control decisions. The development of new application technologies that allow greater control of delivery characteristics (i.e. targeting efficacy, volume and droplet pattern adjustments) could aid the longevity of chemical crop protection strategies.

Figure 1. Spray cards of (A) Flat fan nozzle XR8001vs at 187 L/ha (B) Flat-fan nozzle XR8008vs at 187 L/ha.

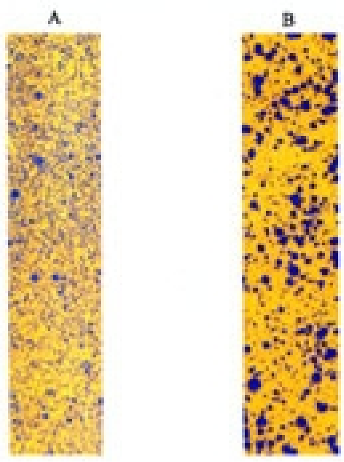


Figure 2. Log dose versus probit mortality for the topical application of technical cypermethrin in acetone on (1) parental generation -(7) 7th generation of fall armyworm *Spodoptera frugiperda* 3rd instar larvae, previously fed on corn leaves sprayed with cypermethrin at 187 L/ha using flat fan nozzle XR8001vs for 72 hours.

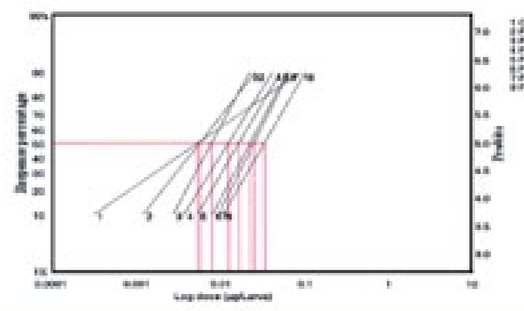


Figure 3. Log dose versus probit mortality for the topical application of technical cypermethrin in acetone on (1) parental generation -(7) 7th generation of fall armyworm *Spodoptera frugiperda* 3rd instar larvae, previously fed on corn leaves sprayed with cypermethrin at 187 L/ha using flat fan nozzle XR8001vs for 72 hours.

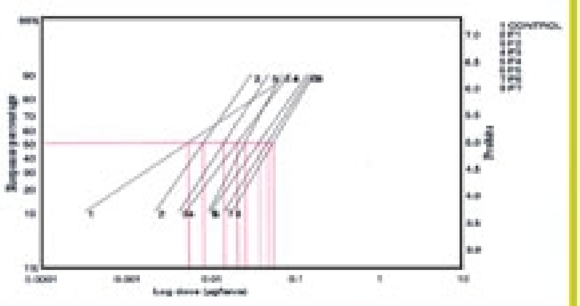


Figure 4. Log dose versus probit mortality for the topical application of technical spinosad in acetone on (1) parental generation -(6) 6th generation of fall armyworm *Spodoptera frugiperda* 3rd instar larvae, previously fed on corn leaves sprayed with spinosad at 187 L/ha using flat fan nozzle XR8001vs for 72 hours.

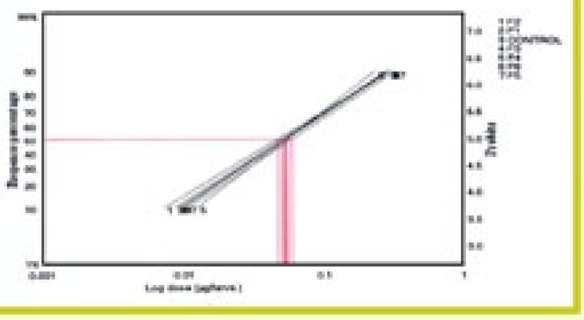
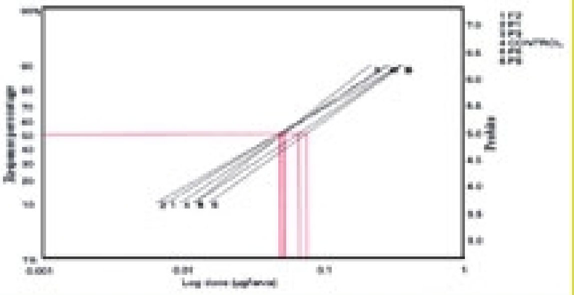


Figure 5. Log dose versus probit mortality for the topical application of technical spinosad in acetone on (1) parental generation -(6) 6th generation of fall armyworm *Spodoptera frugiperda* 3rd instar larvae, previously fed on corn leaves sprayed with spinosad at 187 L/ha using flat fan nozzle XR8008vs for 72 hours.



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