

**STEWARD™ SC FIELD PERFORMANCE AGAINST  
HELIOTHINES: SPEED OF ACTION, SYMPTOMOLOGY,  
AND BEHAVIOR OF TREATED LARVAE**

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**Abstract**

Steward 15% SC is DuPont's new reduced risk insecticide for cotton. Steward's common name is Indoxacarb representing the new class of oxadiazine chemistry. Indoxacarb is registered globally in over 20 countries and actively being applied to cotton. EPA registered Indoxacarb in the US in fall, 2000 but Steward SC was available during the summer to most mid-South, Texas, and Oklahoma cotton growers through a Section 18. Steward is a potent lepidopteran insecticide that provided excellent control of heliothine species when applied during egg stage. Insects that have ingested a lethal dose may not show symptoms until after 24 hours and may not die until 3 days after exposure. Intoxicated insects are sluggish with paralyzed rear abdomens. Affected insects quickly cease feeding and thus begin to shrivel and desiccate and often fall off the plant. Insects sometimes appear to undergo difficulty in molting and digging into the soil to pupate if intoxication occurs just prior to these events. Live larvae present in squares during application are protected and do not pick up a lethal dose until they feed on treated material while seeking new squares. These observations indicate the difficulty in placing spray toxin in the location where heliothine larvae are feeding. And for products like Steward that depend on ingestion as a major mode of entry it emphasizes the importance of maximizing spray coverage and optimizing application technology equipment. Steward maintained control of cotton pests, showing excellent rainfastness despite overhead irrigation applied after spraying. Steward was very effective against *Lygus lineolaris* and observations were made on suppression of stink bug feeding damage to lint. Steward had little impact on parasitic wasps, minute pirate bug, big-eyed bug, lacewings, spiders and predacious mites. These attributes combine to provide consistently high cotton yields and an effective pest management and resistant management tool for growers

**Introduction**

Steward 15% SC is DuPont's new reduced risk insecticide for cotton. Steward's common name is Indoxacarb representing the new class of oxadiazine chemistry. Indoxacarb received full EPA registration status in October, 2000. Indoxacarb attacks a novel site in the insect preventing the normal flow of sodium ions into nerve cells, resulting in paralysis and eventual death. Indoxacarb insecticide is not restricted and has good oral and acute safety resulting in an EPA "Caution" signal word and a re-entry interval of 12 hours. Steward is a 15% suspension concentrate with 1.25 lbs ai per gallon of product. The formulation contains a significant amount of oil and surfactant that enhances leaf wetting and minimizes evaporative loss, typically achieved with tank-mixed combination surfactants, such as a methylated seed oil plus non-ionic surfactant. Field use rates for cotton vary from 0.065 lbs ai/a (6.7 fl oz product) for leaf feeding lepidoptera to 0.11 lbs ai/a (11.3 fl oz) for cryptic feeders and tarnished plant bug (*Lygus lineolaris*).

Steward was applied during the year 2000 to over a million acres of cotton in Pakistan, Brazil, India, and through a Section 18 special-exemption it was also applied in TX, OK, LA, AR, MS, and CA. Specific Heliothine species or combinations were present at all these locations: *Heliothis virescens* (US, Brazil), *Heliothis armigera* (Pakistan, India), *Helicoverpa*

*zea* (US) providing ample opportunity to observe the impact of Indoxacarb on this complex of pests. The remainder of this paper reports observations from field trials and commercial applications that were implemented in 2000.

**Discussion**

**Potency, Mode of Entry, Speed of Kill and Coverage**

Steward is a potent insecticide active against most lepidopteran pests, leafhoppers, specific beetles, hemipterans, fruit flies, leafminers, ants, and orthopterans. Ingestion is the major mode of entry and for most heliothine, spotopteran and looper species the LC50 ranges from 0.5 to 2 ppm. Sprays at field use rates that directly contact lepidopteran larvae are effective but approximately 2 to 10x less potent than by ingestion. Larvae crawling over a dried residual are also susceptible, but compared to product that is ingested, efficacy is reduced from 50-150x depending on the species.

Field studies were conducted in Louisiana in 2000 to measure the impact of dried residual on *Heliothis virescens* larvae. A John Deere Hi-Cycle sprayer applied Steward at 0.1 lbs ai/a in 5.2 gpa at 60 psi to glass petri dishes set on dowels at the same level as the top cotton canopy. Second instar field collected and lab-reared larvae were separately placed on the sprayed dishes for 30 minutes once dried. Larvae were then removed and placed on untreated cotton leaves and evaluated for mortality 72 hours later. In all test replications all treated larvae were dead at the 72-hr evaluation. Although the ppm solution of the tank mix was high at approximately 2000 ppm this experiment shows that Steward provides contact activity of larvae walking over a dried residual without ingesting. An additional study was conducted to measure the response of young Heliothis larvae exposed to treated cotton stems. Realizing that young stems are a major avenue of transportation between squares by larvae, it was important to determine if the retention of Steward residue on stems provided an adequate source of toxin. Steward was applied at 0.1 lbs ai/a with the same equipment and in the same manner as described above. Small stems were collected from the upper canopy one-day post application and assayed with 2<sup>nd</sup> instar larvae for one day. Larvae were then removed and placed on untreated cotton leaves for 72 hours and evaluated. Multiple tests resulted in an average 97% mortality of larvae fed treated cotton stems with a one-day Steward residual.

Laboratory assays allowing ingestion-contact showed that greater than 80% of lab reared *Heliothis virescens* and *Helicoverpa zea* larvae placed on cotton treated by Steward at 100 to 1000 ppm died within 3-6 hours. Cotton treated with Steward at 10 ppm resulted in >80% larval mortality in 18-24 hours and at 1 ppm it took 24-48 hours to achieve the same level of mortality. Separate tests were run with 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> instar larvae and there were no differences in time to kill among the different instars. These tests indicate that reduced rates result in delayed lethal doses taking as much as 2 days more for larvae to die compared to the more potent lethal doses. This may be similar to a cotton field where a continuum of lethal and sub-lethal spray deposits and doses are distributed throughout a crop canopy and available to foliar feeding larval pests.

As with most insecticides, use rates needed to control leaf feeders are significantly less than what is required to control Heliothine cryptic feeders. The following test was implemented to determine if significant toxin enters the square to affect larvae feeding inside. Sprays were made on fruiting cotton using the same equipment and spray methodology described above. Small eraser-size squares were removed 2 days post application and 2<sup>nd</sup> instar *Heliothis virescens* larvae were placed on intact squares. After 72 hours of exposure all larvae fed treated squares were dead. In the same experiment, bracts were removed from eraser-size squares and 2<sup>nd</sup> instar *H. virescens* larvae were placed on bractless buds 2 days post application. After 72 hours of exposure only 25% of the larvae had died and 38% exhibited moribund behavior leaving 37% of the larvae unaffected. This

test highlights the difficulty in placing spray toxin in the location where heliothine larvae are feeding. And for products like Steward that depend on ingestion as a major mode of entry it emphasizes the importance of maximizing spray coverage and optimizing application technology equipment.

#### **Response, Symptomology and Behavior**

Heliothine larvae exposed to a lethal dose may stop feeding within minutes to hours depending on how quickly nerve cells are affected by the blockage of sodium. The cessation of feeding is an extremely strong response by insects even at rates up to 100x less than the LC50. Insects exposed to a sublethal dose eat much less than untreated larvae, develop slower, and gain less weight, delaying the time to pupation and adult eclosion and possibly impacting their survival in the field. The typical response of an insect affected by a lethal dose is the slow onset of paralysis starting at the rear of the insect. The larva's prolegs are partially paralyzed and locomotion is impaired. Coordinated movement of the insect is inconsistent. It is often difficult to diagnose a dying insect within the first 24 hours since these symptoms may be subtle in young larvae. Since feeding is reduced if not stopped completely, larvae often begin to desiccate and appear accordion-shaped and shrunken. Over time, affected larvae often curl into a "C" or "V" shape. In addition, Steward may also appear to cause insect growth regulator (IGR) effects, as larvae treated just prior to a molt may be unsuccessful in shedding old cuticle or pupating. Observations have also been made where affected larvae are unable to dig into the soil to complete pupation.

#### **Timing and Product Positioning**

Steward is as effective against 4<sup>th</sup> instar heliothine larvae (0.68 PPM) as it is against first instar larvae (LC50=0.54 ppm). However, due to the cryptic feeding of these species and the low threshold required to protect squares and bolls, Steward sprays should target egg lay to hatch. Field results have shown that Steward provides excellent control of heliothine populations when they appear in discrete flights and applications are made early. Steward is not recommended for use as a rescue treatment where large worms are present in large population numbers. Performance is compromised when larvae are protected in squares and flowers during application. The feeding behavior of these larvae as they exit protected plant parts and re-enter other cryptic sites may result in insufficient ingestion of a lethal dose of Steward, thus sprays need to be timed when insects are in the egg stage. Relative to crop stage, the ideal time for using Steward during the season is also when plant canopy is less dense and applications are able to better penetrate foliage. Since Steward is most effective when ingested, maximizing plant coverage will result in improved insect control.

#### **Steward Attributes**

The Indoxacarb molecule is unique and is characterized by many attributes that offer a total plant protection package for cotton. The active ingredient represents a novel insecticide chemical class and different mode of action perfect for rotation into resistance management programs. Indoxacarb is extremely potent on its biochemical target resulting in low field use rates (0.09-0.11 lbs ai/a) and excellent safety to workers and consumers, ideal for growers practicing integrated pest management. Indoxacarb is characterized by having low volatility, low solubility, and high lipophilicity. Due to its seed oil/surfactant formulation, Steward™ disperses well over leaf surfaces and is translaminar. Steward penetrates into the leaf's waxy cuticle controlling certain insect pests such as tarnished plant bug and fleahoppers and providing suppression of stink bugs. These physical characters also result in very good rainfastness and good residual activity. Indoxacarb is not systemic. Steward affects moths that have been sprayed directly and is ovicidal to hatching larvae. Feeding cessation by Steward treated larvae is quick and irreversible. There is a strong expression of sublethal effects that delay development and pupal survival that contribute to overall population reduction.

General safety to predacious and parasitic arthropods is attributed to Steward. Predacious beetles are most susceptible but this varies among species and the affect is significantly reduced as residues age beyond 3 days. Steward has little impact on parasitic wasps, minute pirate bug, big-eyed bug, lacewings, spiders and predacious mites. These attributes combine to provide consistently high cotton yields and an effective pest management and resistant management tool for growers.