Evonik's Novel Adjuvants for Drone Application Technology in Agriculture

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Evonik has developed two novel adjuvants, **BREAK-THRU® MSO MAX 522** and **TEGO® XP 11134**, to enhance efficacy and reduce drift for drone applications of agriculture inputs. These novel adjuvants are based on innovative blends of polyether-trisiloxanes with other components. The use of drones for agricultural applications is being adopted rapidly and is a new multifunctional tool for growers for applying pesticides and other functions. Drone use is already widespread in south-east Asia for applying agriculture inputs, but one limit to more wide adoption is the need for optimization to reduce drift and improve both efficacy and efficiency.

Overall, the development of these two novel adjuvants by Evonik is an important step forward in the adoption of drone technology for agriculture applications. By improving both efficacy and efficiency, these adjuvants will help to reduce the environmental impact of agriculture inputs and ensure that growers can continue to produce high-quality crops while minimizing their environmental footprint.

Drones in Agriculture are a multifunctional tool and can be used for:

- Geofencing
- Crop and growth monitoring
- Check crop health
- Crop spraying

Drones for spraying crops have numerous advantages. Drones can have tanks and spray booms attached to facilitate carrying and spraying fertilizers and plant protection products. They can be used to spray crops in later growth stages that cannot be sprayed with a tractor without crop damage. Furthermore, they have utility for fields to small or difficult/dangerous to reach with conventional airplanes and helicopters. Drones also provide a way to spray fields when soil conditions prevent tractor entry to the field. In addition, drones can provide growers with smaller land area or spot spray application a way to limit pesticide exposure as an alternative to a backpack sprayer or hand boom. The spraying process with a drone can be done 5-7 times faster than a tractor which reduces labor and fuel (Figure 1). The drone application can be more precise and flexible and can use less fuel which is an environmental benefit. However, drones may have some disadvantages that need to be overcome. Drones have a smaller payload and in order for them to work efficiently to apply agriculture inputs lower volumes of water are used than in more traditional spray equipment. Thus, the apply pesticides are at higher concentrations than would occur if they were applied with a tractor or manned aircraft. Drones spray volumes ranging from 1 to 40 L / ha compared to ground applications which are 200 L / ha to as high as 1000 L / ha. The spray height of drones is two to four meters above the canopy compared to tractor spraying at 0.3 – 1.0 meters. The increase in spray nozzles height may lead to the potential for increased drift and with reduced volume those off target spray droplets would be more concentrated.

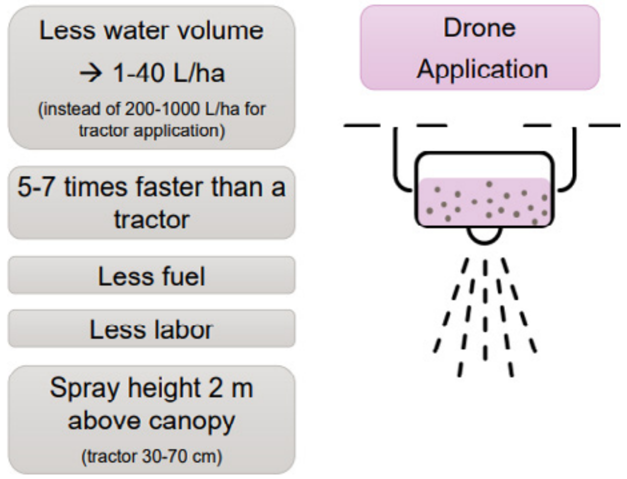

Figure 1: Drone application background

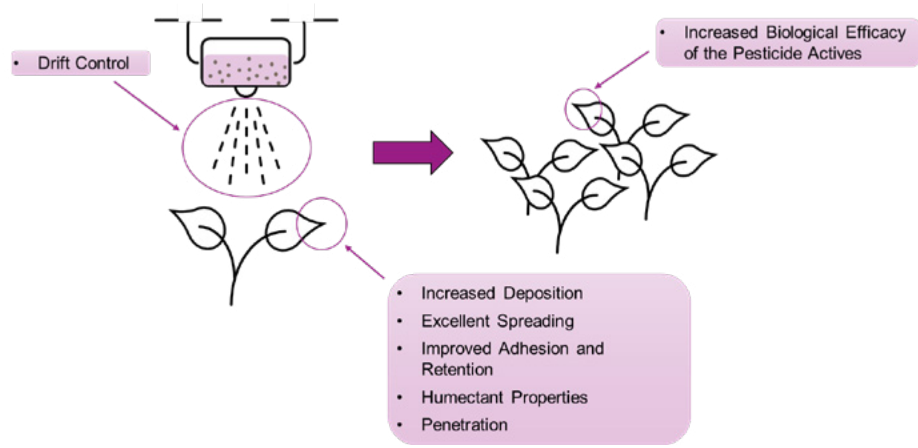

Figure 2: Summary of the properties of an adjuvant designed for drone application.

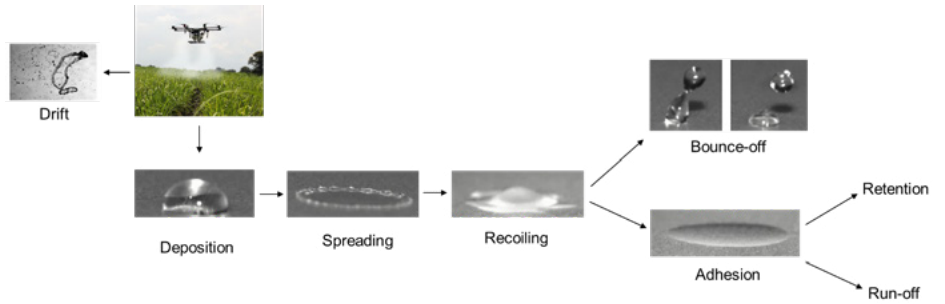

Figure 3: Fate of spray droplets. The lower the surface tension of the droplet, the weaker the recoiling effect and reduced chance for bounce-off. The lower the contact angle the low the chance for run-off and the better the adhesion and retention of the spray droplet.

In order to overcome the unique challenges with drones, adjuvants designed for these applications that optimize spray efficacy and reduce drift are needed. Adjuvants currently on the market for drones have recommended use rates of 0.1% and 1% as a tank side addition. Adjuvants for drones can improve efficacy by improving the surface activity of the spray solution which can increase adhesion, spreading (wetting), and retention of leaf surfaces by spray droplets. In addition, a good drone adjuvant would provide humectant properties to slow drying before the droplet lands on the plant surface (recall the height of drones is significantly greater than tractor sprayers) and to delay drying on the plant surface to increase penetration time. In addition, an adjuvant for drones would be beneficial if it reduces drift.

High Surface activity is required for drone adjuvants

The challenges of a successful spray droplet landing and staying on the intended plant/crop surface are summarized in Figure 3. Once the droplet leaves the spray nozzle it is prone to drift and the smaller the droplet the greater the distance the droplet may move from its intended target. If the surface tension of the spray solution and the interfacial tension of the droplet to the hydrophobic surface is not low enough the droplet will not remain deposited and can recoil and subsequently bounce off. With sufficiently low surface tension a droplet that lands on a plant surface is more likely to spread without recoil and is unlikely to bounce off. Thus, with low surface tension a deposited spray droplet is likely to remain adhered and retained on the surface of the plant as intended.

Drone spray adjuvants need a high surface activity which rapidly reduces the surface tension of the spray solution. The adjuvants also need to encourage an interaction with the hydrophobic leaf surface to reduce the interfacial tension between the droplets and the leaf.

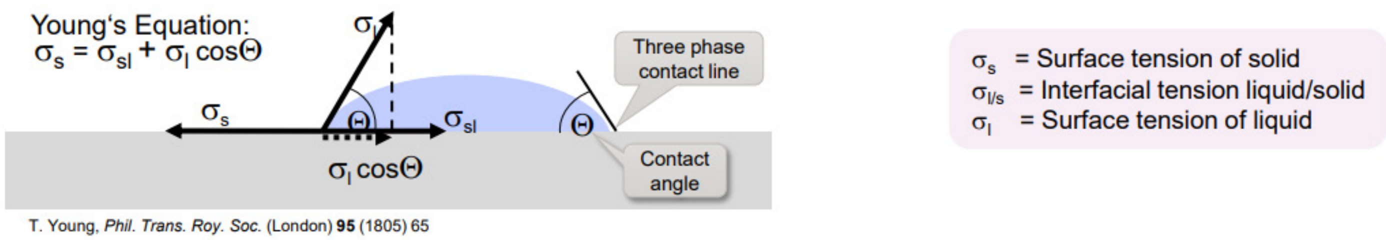

Figure 4: The lower the surface tension of a liquid and the lower interfacial tension between liquid/solid results in a low contact angle.

Water on Cabbage Turnip Leaf   0.05% Polyethertrisiloxanein water

Figure 5: At a use rate as low as 0.05% v/v of a polyether-trisiloxane in water is sufficient to cause the superspreading effect.

The low surface tension of the spray solution and the low interfacial tension leads to excellent retention of the spray droplets (Figure 4). For agricultural tank mix adjuvants for drones, the best performance can be achieved with Evonik's novel adjuvants. These adjuvants leverage the functionality of polyether-trisiloxanes with a blend of other components to optimize them for this specific application. The polyether-trisiloxane component of these adjuvants provide a very low surface tension of water (approximately 21 mN/m) at a low use rate (0.05% v/v). Due to their ability to interact with hydrophobic surfaces they provide an extremely low interfacial tension in the range < 8 mN/m. A typical plant leaf has a surface tension of 30 mN/m, which means a polyether-trisiloxane can cause a spray droplet to have a contact angle of 0°. In addition, these adjuvants cause a superspreading of the spray solution which improves adhesion, retention, and plant surface coverage.

Evonik adjuvants for drone technology are complex blends which provides superior surface tension reduction and plant surface coverage.

Polyether-trisiloxanes can achieve a contact angle of 0° of spray droplets and cause a superspreading effect which leads to an increased coverage of the leaf surface with the liquid water film.

The close contact of the applied liquid to the leaf provides an increased biological efficacy of the plant protection product which can only be achieved with polyether-trisiloxanes. However, drift is an important aspect of a drone application and polyether-trisiloxanes tend to be neutral for drift or provide a small reduction in drift. This is why Evonik has chosen to blend our polyether-trisiloxanes with other components which provide drift control. These novel adjuvants for drone applications are complex blends of surfactants with the ability to improve efficacy and reduce drift.

BREAK-THRU® MSO MAX 522 is a polyether-trisiloxane blended with methylated seed oil (MSO) and a specialized ethoxylated emulsifier mainly for systemic active ingredients. The product provides good emulsion stability in water, drift control, adhesion, retention and spreading. The MSO component forms a solid protective layer on the leaf which increases the leaf permeability up to 10 times. This increased permeability facilitates rapid penetration into the leaf interior. Furthermore, the MSO is a humectant (slows drying time) which reduces the loss of droplet volume before it lands on a plant surface and provides more time for the active to penetrate the leaf surface once on the surface.

TEGO® XP 11134 is a polyether-trisiloxane blended with a special short chain polyether which provides a stable uniform distribution in a tank mix, superspreading effect, adhesion and retention, penetration, and drift control. The polyether component provides humectant properties and much like MSO reduces the loss of droplet volume before it lands on a plant surface and provides more time for the active to penetrate the leaf surface once on the surface.

Basics of drift control in agriculture

Droplets in the range of 105 µm to 210 µm are most prone to drift which can be reduced by adjuvants with certain properties. Typical polymers such as guar gum, polyacrylates, and polyvinyl alcohols are being used to reduce the number of small droplets. These polymers serve to thicken the liquid (increasing its viscosity) and promote cohesion among spray droplets. However, they severely reduce the spray angle by elevating the elongational viscosity. Furthermore, these polymers increase the size of all of the droplets in the spectrum. In so doing, these polymers increase the volume of the spray solution with droplets over 700 µm, which increases the proportion of applied pesticide that will bounce off or run-off. The consequence is a tradeoff between reducing drift and pesticide efficacy (pesticide is lost to the environment) or efficiency (more pesticide is needed on the same area).

Evonik adjuvants reduce drift efficiently without reducing the spray angle

A diminished spray angle must be avoided in drone application to improve coverage uniformity and optimize the limited water volume and significant lower dilution ratios of the plant protection product. Adjuvants that do not maintain the spray angle will lead to insufficient coverage, reduced biological efficacy, and in some situations even crop phytotoxicity. Evonik adjuvants for drone application form insoluble droplets in the spray liquid. These insoluble droplets migrate to the air/water interface of the lamella

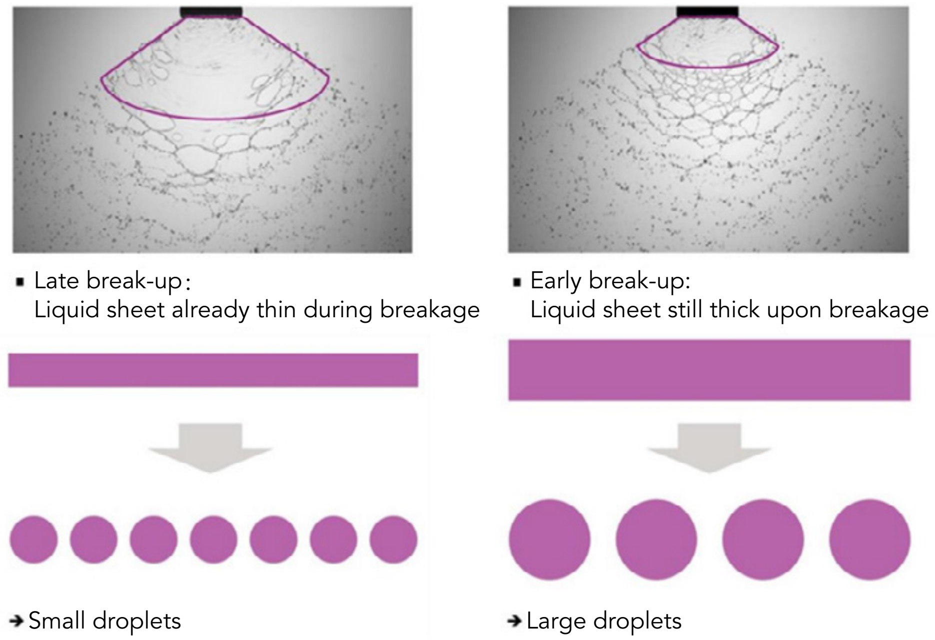

Figure 6: Timing of spray lamella break-up influences droplet size. Top left: Water alone has a late break-up of the liquid film lamella leads to small droplets which are more prone to drift. Top right: Evonik novel additives have early break-up of the liquid film lamella leads to larger droplets which are less prone to drift.

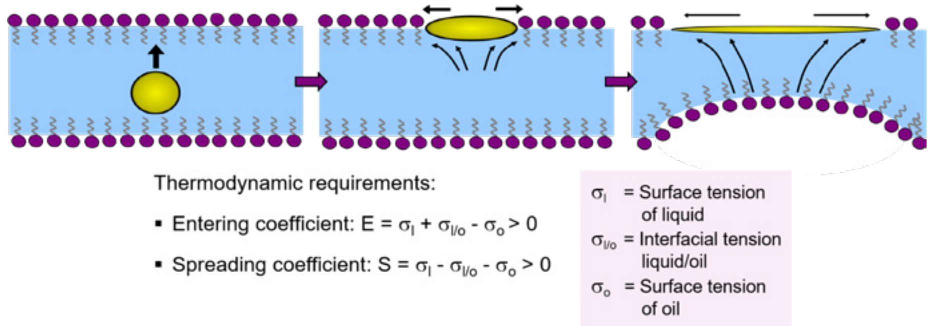

Figure 7: Diagram of thermodynamic effect of somewhat insoluble adjuvant and equations used to describe this behavior.

and cause it to break-up earlier than water. This early break-up of the lamella means it occurs when it is thicker, which produces larger droplets (Figure 6).

The mechanism for an adjuvant to cause an early break-up of the film lamella can be explained by the thermodynamic requirements (Figure 7). Insoluble droplets of the anti-drift adjuvant need a lower surface energy (σ_o) than the spray liquid (σ_l). When this occurs, the entering coefficient remains positive, and the droplets migrate to the surface. To spread on the surface, it is important that surface energy (σ_o) is lower than the spray liquid (σ_l), so that the spreading coefficient remains positive, and the drop has the power to increase its surface area.

Evonik's adjuvants for drones, **BREAK-THRU® MSO MAX 522** and **TEGO® XP 11134**, have the

Table 1. Physical Chemical properties of the adjuvants in this study

	BREAKTHRU® MSO MAX 522 0.1 % in water	TEGO® XP 11134 0.1 % in water
Surface tension in water	26 mN/m	21 mN/m
Contact angle on BOPP*	0°, and spreading	0°, and superspreading

**BOPP is polypropylene sheet*

Table 2. Parameters of the drone and field trial

Drone	Hexacopter with four nozzles
Drone brand	AGRIBOT
Drone manufacturer	IoTechWorld Avigation
Crop	Cotton (Gossypium hirsutum)
Variety	Ajit-155
Plot size	40 m x 76 m
Sowing date	July 10, 2023
Application date	October 12, 2023
Application time	90 days after planting
Thrips at application	above Economic threshold level (5-10 thrips/leaf)
Insecticide	Spinetoram SC*
Water volume	24.7 L / ha
Drone spray height	3 meters from top of canopy
Nozzle type	XR 11004
Flight speed	4 meter/sec (14.4 km/hr)
Spray swath	4 meters
Wind velocity	5.5 km/hr

**Spinetoram SC at 11.7% w/w is sold by Corteva as Delegate SC*

right balance of water solubility to reduce drift because they have low solubility but are not completely immiscible. They have the right thermodynamic requirements to facilitate an early break-up of the spray lamella to increase droplet size without increasing viscosity and decreasing spray angle. In addition, both products show excellent adjuvant properties once on a leaf surface, to give excellent adhesion, retention, spreading of the spray droplet and penetration of the active. Table 1 shows a summary of the physical chemical properties of both adjuvants.

Drone application field trial with Evonik adjuvants

The performance of the novel adjuvants was evaluated in a field trial in India in co-operation with the ICAR-Central Institute for cotton Research (Nagpur, India) with the application conducted with a commercial drone (Table 2). The experiment was designed as a randomized complete block with three replicates. One application of Spinetoram SC was applied 90 days after planting cotton when the population of thrips was above the economic threshold (5 to 10 thrips / leaf). Prior to the application, water sensitive cards

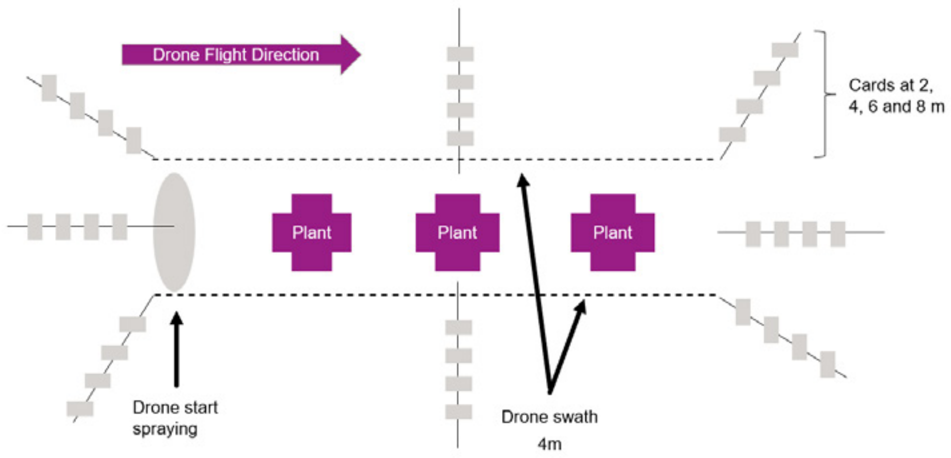

Figure 8: Diagram of each plot in the field trial in India with drone application and Evonik adjuvants in combination with Spinetoram SC in Cotton to control thrips. Each plot was 40 m x 76 m. Water sensitive spray cards (grey boxes) were also placed on plants in the spray swath vertically at the top, middle and bottom of the canopy to assess canopy penetration, deposition and coverage. In addition, water sensitive spray cards were also placed around each plot to assess drift. While spraying, the wind originated from the South-East at an angle of 137 degrees and a velocity of 5.5 km/hr.

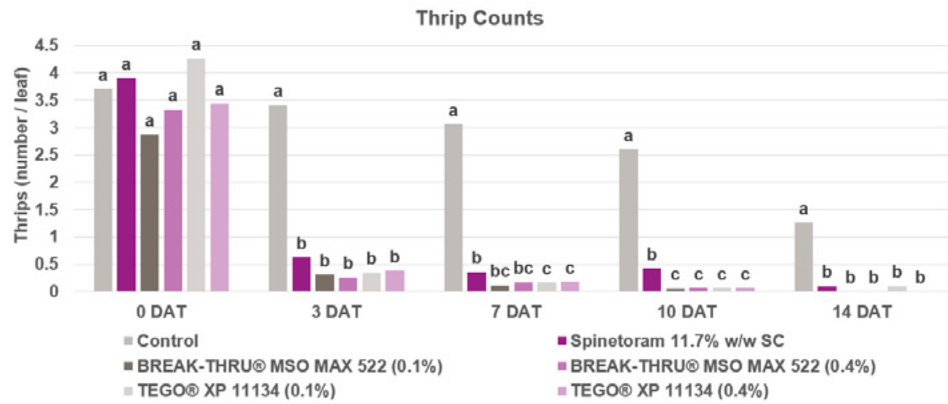

Figure 9: Mean thrip counts per cotton leaf were assess 3, 7, 10 and 14 days after treatment (DAT). Thrip control with Spinetoram SC was increased with tank mix with BREAK-THRU® MSO MAX 522 and TEGO® XP 11134 at low and high rate (0.1% and 0.4% v/v rates, respectively). The mean number of thrips was significantly reduced by Spinetoram SC at all rating timings. Lower case letters that differ indicate significance between treatments (α = 0.05).

were placed vertically at the top, middle and bottom of the canopy within the spray swath to assess canopy penetration and positions outside the spray swath to assess drift (Figure 8). Thrips were counted from 10 randomly selected plants per plot 0, 3, 7, 10, and 14 days after treatment. Thrips were counted on leaves taken at the top, middle and bottom of each plant. Phytotoxicity was assessed at 0, 10 and 14 days after treatment.

In the drone sprayed field trial in India both **BREAK-THRU MSO MAX® 522** and **TEGO® XP 11134** improve efficacy of Spinetoram SC numerically three days after treatment (DAT). **BREAK-THRU®MSO MAX 522** numerically improved control seven DAT, whereas **TEGO® XP 11134** significantly improved control. At 10 DAT both adjuvants significantly improved control of thrips with Spinetoram SC. At 14 DAT there were zero to very few thrips in any treated plots, but it is noteworthy most of the adjuvant treatments had zero thrips (Figure 9). No phytotoxicity was observed for any treatments during this trial.

Data from the water sensitive spray cards outside of the spray swath indicated that drift occurred down wind. Drift for the Spinetoram SC alone treatment reached up to 8 m. Drift with **BREAK-THRU®MSO MAX 522** at 0.1% v/v rate was observed up to 6m. In the treatments with **BREAK-THRU® MSO MAX 522** at 0.4% v/v and **TEGO® XP 11134** at 0.1% and 0.4% v/v rates had drift observed up to 4m. Thus, **BREAK-THRU® MSO MAX 522** and **TEGO® XP 11134** reduced drift from the drone (data not shown).

Data from the water sensitive spray cards inside the spray swath indicated that **BREAK-THRU® MSO MAX 522** and **TEGO® XP 11134** at 0.1% and 0.4% v/v rates improved coverage, deposition, and canopy penetration (Figures 10, 11 and 12).

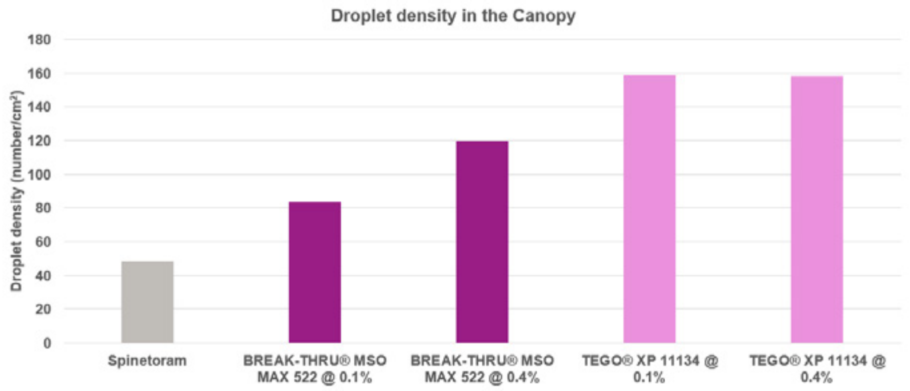

Figure 10: Penetration with Spinetoram SC on spray cards placed vertically at the top, middle and bottom of the cotton canopy was improved with BREAK-THRU® MSO MAX 522 and TEGO® XP 11134 at 0.1% and 0.4% v/v rates. This indicates that both adjuvants improve the number of droplets found through the canopy than the insecticide alone which suggests less off target movement and / or deeper penetration of droplets into the canopy.

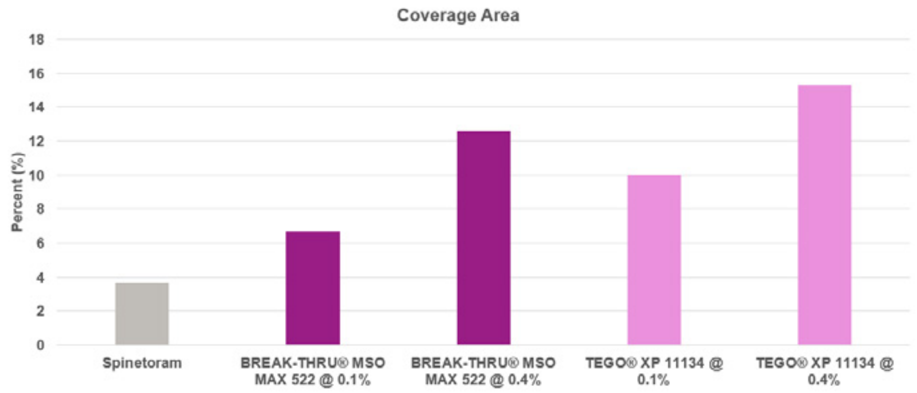

Figure 11: Percent coverage with Spinetoram SC on spray cards placed vertically at the top, middle and bottom of the cotton canopy was improved with BREAK-THRU® MSO MAX 522 and TEGO® XP 11134 at 0.1% and 0.4% v/v rates. This indicates that both adjuvants improve the coverage through the canopy of the insecticide to cover more of the spray card surfaces than the insecticide alone. Note this may be due to reduced drift and / or influenced by humectancy and spreading after landing on the spray cards.

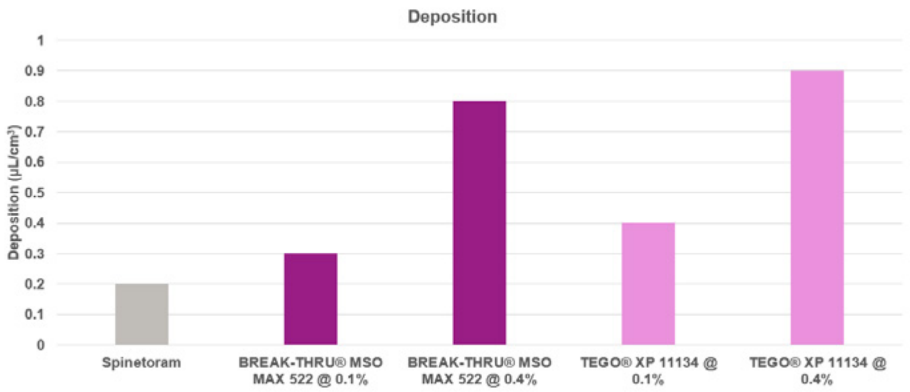

Figure 12: Deposition volume (µL/cm³) is calculated from the number of droplets and size of the droplets per unit are on the spray cards. Deposition with Spinetoram SC was improved with BREAK-THRU® MSO MAX 522 and TEGO® XP 11134 at 0.1% and 0.4% v/v rates. This indicates that both adjuvants improve the coverage through the canopy of the insecticide by delivering a greater volume of droplets than the insecticide alone to the spray cards. Note this may be due to reduced drift and / or influenced by humectancy and spreading after landing on the spray cards.

Conclusion

Through Evonik's innovation we have designed two novel adjuvants, **BREAK-THRU® MSO MAX 522** and **TEGO® XP 11134**, and here provided the science behind how these adjuvants can reduce drift, maintain spray angle, act as a humectant (limit droplet volume loss before landing and increase dry time on plant surface to increase penetration), improve deposition, retention, adhesion and penetration. **BREAK-THRU® MSO MAX 522** and **TEGO® XP 11134** at rates of 0.1% to 0.4% v/v provided excellent biological efficacy of an insecticide to control thrips in cotton under field conditions in India when applied with a commercial drone with low water volume. Other commercial adjuvants used for drone applications have recommended use rates between 0.1% and 1% v/v and both of Evonik's adjuvants have a low relative use rate. No phytotoxicity was observed with either adjuvant at all ratings. The water sensitive cards provided data to demonstrate how **BREAK-THRU® MSO MAX 522** and **TEGO® XP 11134** at rates of 0.1% to 0.4% v/v improve canopy penetration, deposition, coverage, and reduced drift. The results from this study indicate that **BREAK-THRU® MSO MAX 522** and **TEGO® XP 11134** can be used at low use rate and improve efficacy. Furthermore, these novel adjuvants reduce drift and losses from bounce-off and run-off which makes applications with drones more efficient and reduces environmental exposure from agriculture inputs applied with drones. AP

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