Top Interview
Insight Into Requirements, Challenges and Innovations in Formulation and Application Technology

Formulation of Agrochemicals in High Electrolyte Systems
Our portfolio is rich with cutting-edge products, and now that we’re Nouryon, we’re putting even greater focus on innovating with our partners to create shared success and lead the way to a more sustainable chemical industry. Agrilan® 1028 is the latest proven solution from Nouryon — an adjuvant for solving challenges in formulating complex products containing fertilizers or organic salts.

Our agrochemical product line includes well-known brands such as Morwet® dispersants, Adsee™ adjuvants, Agrilan® polymers, Armid® solvents.

Contact us at agro@nouryon.com or visit our website nouryon.com/agriculture.
Nouryon: Formulation of Agrochemicals in High Electrolyte Systems

The need to incorporate agricultural actives (ais) in high electrolyte systems such as fertilizers for in-furrow applications, or in tank mixes for spray applications, provides a significant challenge to the formulator. Many ais have poor water solubility and are often formulated in suspension concentrates (SCs). However, the addition of SCs to a starter fertilizer such as 10-34-0 will often result in a rapid flocculation of the system. This is clearly undesirable; farmers require a system that is sufficiently stable to allow them time to complete their application without the risk of blocked nozzles or uneven application.

SCs use a variety of surfactants and polymers to provide a stable concentrate that can be further diluted to the desired application concentration. However, many of the common surfactants used in SCs don’t perform well in high electrolyte systems due to poor solubility or a loss of stabilization due to depressed electrostatic repulsion effects. Phosphate esters is a category of surfactant that shows good compatibility with electrolyte systems and also offers significant flexibility in design allowing their performance to be fine-tuned.

Phosphate esters are versatile anionic surfactants providing a range of performance characteristics. The variety of raw materials and methods of production provide ample scope for fine-tuning of structure and performance. Phosphate esters are commonly prepared by reaction of an alcohol with either polyphosphoric acid or phosphorous pentoxide. This always results in a mixture of esters, however, depending on the method used you can get a product with a high level of monoester, or a product with a more even mixture of monoester and diester. Figure 1.

![Figure 1. Structure of Monoester and Diester](image)

In our evaluations we found that the degree of ethoxylate on the alcohol was critical and that a sharp fall-off in in-furrow performance was seen, particularly if the product was over ethoxylated by as little as one mole of ethylene oxide. A similar sensitivity was seen in the selection of the hydrophobe and alcohols with the same number of carbons exhibited differences in performance depending on their source. Thus, the source of alcohol and the degree of ethoxylate need to be well defined for optimum performance. For the SC formulations, we found that Agrilan 1028 works best in acid form and its good performance as a wetting agent can eliminate the need for a separate wetting agent.

A comparison of performance of Agrilan 1028 was made against commercial materials recommended for use in electrolyte systems. The comparative examples had the same number of carbons in the hydrophobe and similar levels of ethoxylate as Agrilan 1028. Despite the similarities, the SC made with the Agrilan showed no separation after 24 hours at room temperature whereas the comparative examples both showed clear separation. When these SCs were diluted in 10-34-0 fertilizer the comparative examples started to phase separate after a few hours while the Agrilan 1028 formulation remained stable for 24 hours, Figure 2. This result confirmed our original findings that the specific alcohol used, degree of ethoxylate, and method of manufacture are key to achieving stability in both the SC and the fertilizer dilution.

![Figure 2. A comparison of performance of Agrilan 1028 was made against commercial materials recommended for use in electrolyte systems.](image)

**Property** | **Mono-ester** | **Di-ester**
--- | --- | ---
Hydrolysis | Excellent | Poor
Electrolyte tolerance | Excellent | Poor
Sticking | Good | Poor
Emulsification | Good | Fair
Dispersion | Poor | Good
Water solubility | Poor | Poor
Table 1. The ester distribution impacts the surfactant’s performance

Our initial goal was to identify a surfactant that would provide a stable suspension concentrate that could be further diluted in a 10-34-0 starter fertilizer to afford a stable mixture. To achieve this a fine balance of surfactant properties was going to be required. While much of the effort was directed towards Bifenthrin and Imidacloprid as the ais other actives were also screened, as were other fertilizers.

A significant number of phosphate esters were tested before finding one that afforded a stable SC that diluted well in 10-34-0 fertilizer. Fine tuning of both the process and the structure resulted in Agrilan® 1028. Agrilan 1028 is a phosphate ester based on an alcohol ethoxylate. It has a high monoester content and is both TSCA and FIFRA listed; it also falls under the Reach polymer definition.

![Figure 3. The results with different fertilizers and actives after 6 hours of standing](image)

Our initial focus was on in-furrow applications, but we also were interested in tank mix formulations. To evaluate the potential of Agrilan 1028 as a tank mix compatibility agent we looked at a 3-component mixture. For this evaluation, 4 commercial 540K Glyphosate formulations were used alongside 4 formulations utilizing our own actives. Added to these solutions were an Atrazine WDG and a Trifluralin EC. All these 3-way component mixtures flocculated upon mixing. However, this could be avoided by adding Agrilan 1028 – the addition of 0.5% Agrilan 1028 gave full compatibility with no phase separation or flocculation in all 8 cases.

**Conclusion**

Formulation in high electrolyte systems severely limits the tools available to the chemist. Due to the complexity of many agrochemical formulations the ability to fine tune surfactant properties to meet the formulation challenge is highly desirable. We have seen that some systems can be sensitive to relatively small differences in surfactant structure. Phosphate esters have been shown to be a useful surfactant class for this application due to the variety of structural options they provide and their tunable surfactant properties. Phosphate esters, in particular Agrilan 1028, have proven to be a versatile addition to our toolbox when working with high electrolyte systems.

**Table 1. The ester distribution impacts the surfactant’s performance**

**Property**
- Hydrolysis
- Electrolyte tolerance
- Sticking
- Emulsification
- Dispersion
- Water solubility

**Ester Type**
- Mono-ester
- Di-ester

**Performance**
- Excellent
- Good
- Poor
- Fair
- Good
- Poor
Future requirements, challenges and core competences in formulation innovation and development

“Regarding the formulation technology innovation, an agrichem company core competence should have the following strategies and objectives: 1) developing new pesticide molecules, 2) discovering new biopesticides, 3) design formulations of either single or combo AIs (both new and generic) with the aim of effective, safe co-formulants, and 4) manufacturing the resultant formulation products in a safe and cost-effective manner, which should be deliverable and efficacious for the farmers,” said Roy C. Chen, PhD, ADAMA US Formulation Leader, in a recent interview with AgroPages. He also shared his views on the future development trends of novel formulation and application technologies, regulatory and R&D challenges that affect formulation innovation and development, as well as core competence to drive formulation technology innovation.

What novel formulation and application technologies are needed to meet the needs for growers over the next 5-10 years in different global regions?

In the next 5 to 10 years, the worldwide population will demand more secure and reliable food crop production, in terms of quality and quantity, while adjusting to climate change and reduced arable land. The future of noble formulation technological development for agrochemical companies will center around developing not only new AI molecules by R/D companies, but also combo AIs, or so-called hybrid mixture formulations by most generic companies. The latter direction is due to the need to differentiate oneself in local and global market places. Furthermore, there is also a desire to be environment-friendly, while keeping safe and efficient applications, and breaking weed resistance, such as those of glyphosate and triazines, among others. Formulation technology could be part of an integrated approach involving a weeder machine, and crop rotations in conjunction with novel agri-formulations.

How about using chemical/biological combo formulations to fight against resistance? For example, one could use certain fungal spores in the formulation. The major formulation challenges lie in dealing with formulation mixtures which are becoming more complex, so do the coformulants needed to make that happen. Usually, these include new functional co-formulants, green solvents, biostimulants and other related adjuvants.

What are the regulatory challenges to affect future formulations? Could you share some specific cases of how an agrichem company develops agrochemical formulations suited to different global regions?

As national authorities manage formulation registrations individually, through various local laws and policies, agrochemical producers may face challenges in cases of the same co-formulants which may not be globally accepted. Therefore, separate versions of the same product formulations may be necessary, so do the corresponding tox data requirement. As a result, more resources are needed for registering the same product. By the same token, managing the downstream supply chain issues would be just as challenging and costly. Furthermore, due to different pesticide regulations among countries, there could be issues involving pesticides in international trade. A recent example concerns glyphosate re-registration in the EU. Because Glyphosate formulations, particularly those coupled with polyethoxylated tall oils emulsifiers (POEAs), have been shown to cause elevated cytotoxic or endocrine disrupting effects, compared to the active ingredient glyphosate. However, this is not an open and shut case for some. Opinions among scientific communities, health officials and environmental authorities/organizations are divided. Essentially, the case touches upon fundamental aspects of risk assessment and product regulation. A very recent news item is that a French court has issued a ban on glyphosate sales in France. Several other countries outside the EU, including Argentina, Australia, Bermuda, Brazil and Canada, are banning or restricting glyphosate use, while the US has not. Because of the glyphosate issues, the fate of POEAE Tallowamine coformulant has also been affected. In response, Bayer/Monsanto, the glyphosate formulation manufacturer, is now removing the Tallowamine emulsifier away from all glyphosate formulations. There is also movement in the EU to use alternative weeding methods, in addition to IPM techniques, plus using other safe organic herbicides, such as essential oils, acetic and citric acids, as well as fatty acids, as in soap formulations which may be necessary to help manage post-glyphosate market needs.

What are the challenges in R&D for new formulations and possible solutions?

In the broad background of satisfying the overall agricultural production needs in food, fiber and fuel crop productions, farmers usually rely heavily on agrochemicals in modern farming to enhance crop yield, increase plant growth, neutralize the soil, and protect against pests, including weeds, insects, and fungi. The issues are how to increase and optimize the agricultural output in each region through smart utilization of agrochemicals. The corresponding formulation R/D challenges resides in developing new combo formulations, which are becoming more complex to formulate. Take a close look at potential formulation components that a formulator must face; including the chemical active ingredients, wetting agents, emulsifiers, surfactants, dispersants, polymers, solvents, oils, adjuvants, suspension aids, powders, buffers, rheology modifiers, water, adjuvants and more. Their physical and colloidal interactions with one another must be appreciated and acted upon accordingly. Obviously, the goal is to have an end formulation product which must be physically and chemically stable in storage, and easily applicable for tank mixing, while delivering the pesticidal efficacies.

More challenging are those combos of agrochemicals and biopesticides. For example, there are biopesticides consisting of bacterial or fungal spores for seed treatments, combined with the chemical insecticide on crop seeds, such as corn, soybean, and cotton. The seed treatment combo formulations may be one of the reasons why the biopesticides market is growing. Prominent examples are BASF’s Poncho Voto and PV 2.0 (nameticide) and Syngenta’s Clariva Complete (Soysoybean Cyct Nematicide).

Could you share some cases of digitalization technologies that enhance efficacy for formulation development / application/ delivery?

As we are living in a digitized world, it is only natural that digital technology can be utilized or considered in agrochemical formulation development, such as data collection and organization for formulation definition and registration purposes. Databases of co-formulants, including their chemical and physical properties, can be searched for data mining. For now, there is still no computer modeling or simulation of agrochemical formulations. Actual formulations still need to be put together physically, according to compositions on the bench for realistic testing and monitoring. This is an area yet to be explored.

A very useful statistical methodology applied to formulation development is the “Design of Experiment” (DOE). It is a well-established systematic approach to create good formulations. There are commercial computer software packages marketed to perform formulation DOE. This statistical method is a powerful tool for formulation optimization, particularly when multiple ingredients are involved to achieve the final performing formulations. Generally, DOE technique is highly recommended, as most formulators have been trained or are used for employing traditional techniques of changing one-variable at a time (OFAT), versus something like factorial designed experiments through DOE techniques.

Other areas of agrochemical digitalization start from digitizing lab formulation test equipment, which can be computer controlled and monitored, and examples include lab viscometer and incubators for freeze-thaw tests. Regarding the downstream agrochemical pilot plant operation and the further down-stream production, the associated digitization is expected to follow those of a digitized chemical plant, both in unit operation and unit process. From plant control panel to process unit feedback, modern digital technology can be a great tool, in terms of safety and good quality control. One critically new area for all agrochemical companies to consider is the formulation production simulation for formulation plants. Not only can a normal formulation operation be simulated, but also an inaccurate formulation mishap. A simulation software module can be a cost-effective training tool for pilot scale up and production crews. The final area to consider is formulation plant automation. This can be an effective way to increase productivity, minimize costs and make your facility...
operate more ergonomically. Plant automation should be well suited to a stepwise type of processing for a production facility which manufactures agrochemical formulations.

In the near future, delivering formulations to the field will be done by robots in modern farms, usually by Agbots plus flying drones. Accordingly, agrichemical formulations can have higher concentrations, while formulation types and design also can be more versatile, without human safety concerns. For the same reason, formulation sprays can be more flexible, as well.

Furthermore, formulation application can be performed in a high precision manner and be far less polluting to the environment.

**Q5**
What's the core competence to drive formulation technology innovation in an agchem company? What innovation formulation technologies have been launched in the agchem industry?

As far as a modern agrochemical company is concerned, regarding the formulation technology innovation, the company core competence should have the following strategies and objectives: 1) developing new pesticide molecules, 2) discovering new biopesticides, 3) design formulations of either single or combo AIs (both new and generic) with the aid of effective, safe co-formulants, and 4) manufacturing the resultant formulation products in a safe and cost-effective manner which should be deliverable and efficacious for the farmers.

Furthermore, regarding the formulation technology innovations necessary to follow up the above strategies, the agrochemical company needs to excel in the traditional formulation technologies such as the emulsifiable concentrate (EC), soluble concentrate (SL), suspension concentrate (SC), water dispersible granule (WG), and wettable powder (WP) by Improving and optimizing the compositions. Have a pipeline of formulation products each year for the market. Beyond the traditional formulations, other specific formulation types may be considered, such as suspo-emulsion (SE), oil dispersion (OD), and capsule suspension (CS) formulations utilized to deal with the specific cases including physical or chemical incompatibility, bioefficacy improvement, reduced environmental toxicity, etc. Typically, these formulation types require longer time to screen and test. Lastly in the case of microbial spore biopesticides, the up-stream fermentation excipients usually are mingled with the spores in the very formulation mixture, that can be a challenge to the formulators!
Bayer, Corteva Agriscience and ADAMA: Insight into the Innovation and development of Formulation and application Technology

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The agrochemical formulation development is facing significant challenges not only from a technical perspective, but also regulatory and market demands. These challenges facilitate the iterative upgrading of formulation and application technologies. It is worth mentioning that the digitalization technologies are enhancing both formulation development and the application of delivery of products. AgroPages recently invited three key players Bayer, Corteva Agriscience and ADAMA in this field to share their views on future development trends of novel formulation and application technologies, challenges that affect formulation innovation and development, strategies of formulation development, digitalization technologies to enhance efficacy for formulation development/application/delivery, as well as innovation formulation and application technologies launched by them.

Q1: What novel formulation and application technologies are needed to meet the needs of growers over the next 5 to 10 years in different regions of the world?

Bayer: New advancements in application technologies, such as drones, direct-injection systems and autonomous field robots, change the way our crop protection products are applied. Improvements in sensor-technology and image recognition, combined with ultra-fast computing power, are allowing high-resolution weed detection and increasingly precise disease and pest prediction, which form the basis of new service offerings for our customers.

The fundamental formulation solutions and approaches will not change. Nevertheless, I believe that the overall relevance of formulation technologies will increase in the future, specifically as the rate of introduction of new active ingredients has declined in recent years. Formulation technologies have to meet increasing regulatory requirements for reducing the environmental impact, such as the reduction of off-target losses, biodegradability and also technical challenges resulting from new active principles such as biocontrol solutions, peptides, and RNA-based or antibody-based solutions. However, this will also help to generate IP and introducing new competitive solutions.

Further advancements in formulation sciences are key to improve bio-delivery, reduce environmental impact, ease handling and increase stability, particularly in low-volume applications by drones, boom-sprayers and robot applications. These features are quickly becoming key selling points for our customers, and increase the perceived value for important Bayer product brands.

Another example of the relevance of formulation technologies are innovative solutions allowing a slow-controlled release of active ingredients, thereby improving crop safety and duration of control in soil or paddy fields. Encapsulation technologies can also reduce the volatility of active ingredients, chemical compatibility and the shelf-life of biological crop protection products. Other formulation technologies aim at reducing off-target losses, such as dust from seeds, drift, wash-off or improving rain-fastness.

Finally, despite their relatively low market share today, biologicals (or biopesticides) will offer clear growth opportunities for our industry in the future. Due to the active nature of biological crop protection products, formulation technology will help to address challenges around shelf-life, formulation stability and the efficacy of these solutions.

Corteva Agriscience: It is an exciting time for agriculture with new advances in active ingredients, biotechnology, application technology and data science all impacting new product development. Despite rapid change in many areas, the macro-level trends continue to be consistent. Growers require convenient products and solutions that maximize yield potential in a cost-effective manner, while enabling them to be good stewards of the land, environment, and human health. Growers will continue to need easy-to-use solutions to address resistance challenges through multiple modes of action. I expect there to be significant growth in naturally-derived and biological control products coming to the market to meet the increasing public and regulatory pull for these types of products, especially in some highly developed regions. Additionally, product sustainability in terms of low use rates, as well as use of low environmental-impact and inherently safe co-formulants, will be prevalent. Application technologies that enable crop protection products to be applied only where needed will also be required to continue to improve the profitability and environmental footprint of agriculture.

ADAMA: Growers today are facing multiple challenges that are driving two primary industry needs.

The first challenge is presented by the growing resistance to the different crop protection products that are being applied around the world. This phenomenon is quite similar to what we’ve seen in the pharma industry – where different bacteria are becoming immune to the antibiotics that have protected the world’s population against illness for decades - although possibly escalating at an even faster rate.

In the AgChem industry, such resistance is posing great challenges to growers. Namely, as pests become more resistant, more products need to be applied at a higher frequency. Clearly, this bears great financial and ecological consequences.

In some cases even increasing application rates and frequency does not effectively control the disease. As a result, output decreases, crops are lost, and prices increase. In fact, there is no part of the supply and value chain that is not impacted.

One example of resistance comes from black grass, a weed that is particularly prevalent in Europe, but also beyond. Black grass grows next to cereal crops, such as wheat and barley, adversely impacting yields. Despite the variety of herbicides applied to combat it, black grass has developed resistance to most products and requires increased application rates of others.

Another example comes from a fungal infection called Asian Soybean Rust, common in Brazil and surrounding countries, including Bolivia and Paraguay. Over the last number of years, this fungal disease has developed significant resistance to existing fungicides and has caused profound economic losses to both farmers and the food chain.

For effective resistance management, plant protection products based on several chemical classes and different modes of action need to be available to farmers. The development of new formulation and application technologies needs to evolve accordingly. We need to be innovative and user-focused in our approach, while balancing the various and competing factors we need to take into consideration, including environmental, regulatory and financial aspects.

While players in the industry are working hard to bring new innovative active ingredients (Alts) to market, the rate of innovation appears to be slower than the rate of the evolution of resistances. As soon as a new product is launched, work on the next one needs to start, if not before.

The second challenge that farmers face is the often adverse public perception of the environmental and health impact of plant protection. As ADAMA we understand that societal challenges resulting from new active principles such as biocontrol solutions, peptides, and RNA-based or antibody-based solutions. However, this will also help to generate IP and introducing new competitive solutions.

Further advancements in formulation sciences are key to improve bio-delivery, reduce environmental impact, ease handling and increase stability, particularly in low-volume applications by drones, boom-sprayers and robot applications. These features are quickly becoming key selling points for our customers, and increase the perceived value for important Bayer product brands. Another example of the relevance of formulation technologies are innovative solutions allowing a slow-controlled release of active ingredients, thereby improving crop safety and duration of control in soil or paddy fields. Encapsulation technologies can also reduce the volatility of active ingredients, chemical compatibility and the shelf-life of biological crop protection products. Other formulation technologies aim at reducing off-target losses, such as dust from seeds, drift, wash-off or improving rain-fastness.

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Q2 Could you share some specific cases of how your company develops agrochemical formulations suited to different global regions?

Bayer: One example is in Europe, as well as the cereal market where EC Fungicide formulations with good leaf activity and penetration of cereal fungicides are needed. In North America, we typically develop liquid formulations, such as SL-type herbicides or non-adjuvanted SC-type formulations, in light of the established strong tank-mix adjuvant market. In the Asia-Pacific region, and especially in Japan, we focus on specialty solutions for rice growers. For example, we develop shaker bottle solutions, granules and jumbo granules, and there is a growing market for drone applications with a need for ultra-low water volumes. In Latin America, where the market is dominated by large farm operations, there is a particular need for the easy handling of products and preparation of spray solutions.

Corteva Agriscience: The development of any new agricultural product at Corteva Agriscience starts with the customer in mind and a clear understanding of local application practices in the targeted markets and regions. Corteva Agriscience has a global R&D presence for both formulation and application technology – in North America, Latin America, Asia-Pacific, and Europe – to ensure that we can easily collect first-hand knowledge of local application practices and test our products under relevant conditions, often in partnership with growers and applicators.

For example, a product that will be applied by backpack sprayer needs to have excellent “bloom” upon addition to water because mixing in the application is uncertain. Products designed for the northern United States and Canada need to disperse quickly in cold water, and products designed for drone application in Asia should have exceptional compatibility at high concentration to maximize payload. Our scientists take these and many other region-specific considerations, such as typical equipment, water quality, application rates, and storage conditions into account when developing design and testing protocols for both the lab and field to ensure a positive applicator and grower experience.

ADAMA: Our product development process starts with ideation. That is, first we investigate and identify the needs of growers in different regions of the world. We translate these needs into product concepts, and then make decisions about which products we want to develop and prioritize.

A variety of functions are involved in this decision-making process, including local as well as global assets. This ensures that we stay close to the local needs, even as we build on our wider global resources.

Indeed, our product concepts come from the field – literally. It’s not just about headquarters bringing in the ideas and making decisions. The countries themselves are deeply involved.

As a company, we are locally driven and globally backed. We have a presence in 50 countries, endowing us with great access to nurturing mutually-beneficial relationships with farmers. And the result is a product development process that is tailored to meet the specific needs of farmers in every region and key market.

At ADAMA, we invest in both internal and external capabilities. We are expanding our internal resources, and recently opened two new state-of-the-art R&D centers, in Nanjing, China, Hyderabad, India and the recently launched R&D center in Beer-Sheva, Israel.

In addition, we’ve also established more third-party partnerships, in order to accelerate our access to innovative technologies and methodologies.

I would highlight our network of agronomists located in dozens of countries, a number of local formulation labs, including in Israel, India, Brazil, China, and the US.

Beyond resources, I believe that our culture and mindset enables us to react rapidly to change, to be agile, and to innovate in the way we connect the needs of the market to our expertise and ability to deliver on them.

I am proud of how we mold local with global, and apply agility and an innovative spirit to many things we do daily at ADAMA.

Q3 What are the challenges in R&D for new formulations and possible solutions? What technologies has your company adopted to speed up formulation technology innovations?

Bayer: Our R&D efforts are focused on a variety of key areas. For example, we devote a lot of time on environmental and human safety aspects of our formulations, such as reducing the off-target movement of products or further minimizing risk to operators. We work a lot on areas around mixing, including developing premixes with multiple active ingredients to ensure chemical compatibility, or compatibility with tank mix partners, such as fertilizers. And product quality measures are critical: stability of products, efficacy and shelf-life, and robustness of the formulations.

To continually improve our ability to bring new innovations to the market, we rely on our extensive background in formulation design with the latest data science tools. Over the past decades, we have gathered a wealth of formulation recipe data and related analytical data (chemical and physical stability data), as well as data from bioavailability and efficacy testing of various formulation concepts. Making best use of these data sources remains a key challenge, but also offers a great opportunity for us. It is important for us to continue establishing data platforms for data capture in the formulation space and also improve our data analysis capability by combing formulation data with analytical and biological data, in order to make better predictions for the design of formulations.

At the heart of all of this advancement is our people. We have formulation expertise built on diverse and comprehensive experiences with colloid scientists, chemists, physicists, biologists, biotechnologists, people with engineering backgrounds, and more. We built an internal formulation community across the various Bayer divisions for know-how sharing, and we collaborate and exchange with universities to foster fundamental science in the formulation area, and to have access to talents.

Corteva Agriscience: Corteva Agriscience is working to develop new products that address the opportunities and unprecedented challenges of the rapidly-changing agricultural marketplace. For example, we are developing multi-active ingredient products with multiple modes of action to help farmers manage weed, insect, and disease resistance. Stabilizing multiple active ingredients in a formulation can be a challenge, but predictive models and data science are becoming valuable tools to help screen initial formulation parameters and focus research quickly on leading prototypes. New predictive test methods and technologies enable formulation scientists to effectively evaluate physical stability of formulations, like crystallization or phase separation potential, before these effects can be observed by the human eye. We also use predictive methods to proactively understand the human and environmental safety of our products during development, so we can ensure the safest and most sustainable products make it to the market.

New analytical tools allow scientists to measure and visualize with more definition whether the active ingredient is reaching its target site and subsequently modify formulation and application parameters to maximize efficacy without relying solely on biological response data. These tools are particularly useful as active ingredients become more complex and efficiency is critical to ensure cost-effective solutions for the grower.

ADAMA: As pest resistance increases quickly, one of the challenges to R&D is undoubtedly shortening the development process for new formulations. Every market player wants to be the first to market. But with resistance playing a major role in our industry, there is a greater sense of urgency than ever to accelerate the process of getting a product from the research stage to the end user. Resistance cycles are getting shorter and shorter, and we simply can’t afford not to keep up.

Moreover, with the increasing demands of our regulatory environment, accelerating development cycles has become an even more complicated endeavor. There is a lot of uncertainty, where you can be working on a product for perhaps three years. On starting the registration process, you might discover that regulation has been passed during the development period. At that point, the formulation and application rates of the product might have to change, and you find yourself back to square one.

Q4 Could you share some cases in the digitalization technologies that enhance efficacy for formulation development/ application/delivery?

Bayer: Digital tools are enhancing both formulation development and the application of delivery of products. In Development, we use modeling and prediction tools to speed up screening or to simulate operating environments. We are also able to use robot technologies in formulation screening to improve accurate handling and dosing of a large range of active ingredients and formulation inerts.

Digital tools are rapidly changing how our products are used. For example, digital weed control is being used on railways. With partners, we have developed a train equipped with camera systems to detect weeds, which opens spray...
control of resistant and hard-to-control broadleaf weeds in Enlist E3 soy, Enlist corn and Enlist cotton fields — including Palmer amaranth, waterhemp and giant ragweed. Both products use new 2,4-D choline and Colex-D® technology to help address challenges beyond controlling tough weeds, including minimizing potential for physical drift and delivering near-zero volatility to ensure that the product lands and stays on-target. Colex-D technology also provides applicators the benefit of better handling.

As farmers continue to fight herbicide-resistant weeds, Resicore® corn herbicide brings together three modes of action and a wide rate range to fit a variety of agronomic programs, including pre-emergence and post-emergence. Resicore® corn herbicide gives farmers power over weeds deep into the growing season. With strong residue control and versatile application timing, Resicore controls more than 75 high-anxiety broadleaf weeds and grasses, including waterhemp, marestail and Palmer amaranth. Resicore® was awarded the Agrow Award for Best Formulation Innovation 2016.

Loyant™ herbicide, with Rinskor® active, provides excellent control of ALS-resistant grasses and sedges in rice with an alternative mode of action. The product received a U.S. EPA Reduced Risk designation for its favorable environmental profile and was recognized by the US Green Chemistry Challenge Award. Also, Rinskor™ has been recognized by R&D 100 and by Agrow as the Best New Crop Protection Product. Loyant™ herbicide utilizes novel NeoEC formulation technology, to deliver a similar sustainability profile to water-based formulations, while also achieving many of the benefits traditionally associated with solvent-based formulations, including high efficiency, good stability and excellent handling properties.

Pexalon™ Insecticide, powered by Pynoxyl® active is a crucial insect management tool specifically for rice farmers in Asia. Pexalon™ can control damaging plant and leaf-hoppers with one application, followed by a different mode of action chemistry, reducing the number of spray applications compared with traditional treatments due to the long-lasting nature of control and excellent rain-fastness.

ADAMA: ADAMA strives to create simplicity in agriculture— with one of the most comprehensive and diversified portfolios of differentiated, high-quality products, we provide farmers around the world with crop protection solutions that help to produce safe and nutritious food for a rapidly growing population.

Soybean rust is a highly impactful disease which causes significant damage. It is particularly destructive since it can develop very quickly, be carried by wind over large distances, and cause rapid, irreparable loss of leaves, with the possibility of causing crop losses of up to 80%. In 2018, ADAMA launched a unique three-way mixture fungicide to combat soybean rust, CRONONS® (picroxyconazole + Tebuconazole + mancozeb). Its liquid formulation, CRONONS TO® provides effective protection for soybean diseases, saves time for growers by strongly adhering to the plants’ leaves and preventing spray nozzles from clogging. Its flexibility provides farmers with further benefit by being able to apply the fungicide at any time during the plant’s development.

BREVIS® (metamitron) was developed with the aim to replicate the known effects of shade thinning on apple and pear trees and is the most effective Carbaryl substitute among all other thinning candidates. It combines a photosynthesis inhibitor and a commonly used fertilizer (Calcium formate). For the last 6 years ADAMA has been testing and improving the formulation of BREVIS® in a wide range of varieties, growing conditions and geographical zones (Europe, Americas, Asia, Africa, and Australasia). BREVIS® is now registered in 23 countries worldwide, with other key apple and pear markets to follow in the coming years. BREVIS® is an innovative product now patented in Europe and other countries globally.

Q5 What is the core competence that drives formulation technology innovation in your company? What are the agricultural concerns solved by them?

Bayer: Our core competence is combining the vast knowledge and experience we have across Bayer in a wide range of disciplines, such as chemistry, biology, field development, application technology, and more. To do this, we have an in-house innovation platform in the formulation area, which allows exploration of blue-sky ideas and new formulation concepts, and ensures cross-site know-how exchanges between different formulation teams.

And while we have an excellent understanding of product performance attributes, such as efficacy, application behavior and shelf life stability, we continually look outwards to improve. For example, we partner with our commercial teams to ensure sound understanding of market needs and involvement in the design of new commercial product concepts to best meet our customers’ needs. And we actively collaborate with universities and other outside experts to expand knowledge and perspective.

Recent launches demonstrating how formulation technology enables new product concepts:

- Bayer, inventor of Oil Dispersion technology for a range of highly potent herbicides, e.g. Laudis®OD, and newer introductions, such as Maxter® Power / Monson® active OD, oil required for chemical stability of SU herbicides and boosting biological efficacy.
- XtendMax® Herbicide with Vapor Grip Technology to minimize off-target losses and vapor drift of dicamba
- Fox™ Xpro Fungicide in Brazil, our new benchmark fungicide for outstanding soybean rust control combining 3 different modes of action with SDHI chemistry (Bixafen), azole (Prothioconazole) and strobilurin fungicide (Trifloxystrobin) providing superior performance through innovative formulation technology, such as adjuvants for improved wetting and rain-fastness.
- K-Othrine™ Polyzene, an example of a new innovative formulation which added new features to an existing pyrethroid insecticide via a polymer-enhanced suspension concentrate, which provides excellent long-lasting control (used for in-door control, e.g. mosquito).
- Specticle™ Herbicide for pre-emergence weed control in turf. The challenge was to avoid movement of herbicides into the turf root zone, which has been achieved through the addition of suitable polymers / carriers.

Upcoming new launches include:

Vayego™ Insecticide based upon novel diamide chemistry for lepidopteran control, where the technical quality (i.e. crystal modification of the active ingredient) posed significant challenges during formulation development.

New developments based on RNAi:

- BioDirect, RNAi for varroa control - We recently submitted a new Varroa Control Product to the U.S. EPA for registration, based upon double-stranded RNA, which is the first U.S. EPA submission for an exogenously applied, dsRNA biotechnical active ingredient in the industry. Contributions from formulation technology were key in developing this new technology, ensuring sufficient stability and uptake of this new active ingredient principle.

Corteva Agriscience: Developing formulation and application technologies that are efficacious, sustainable and easy-to-use requires collaboration among our highly skilled and diverse chemists, engineers, analysts, and field scientists. However, at Corteva Agriscience, the most important element is a deep understanding of what growers and consumers need and value — at a local level — that can be translated into exciting new products. Examples of our award-winning formulation and application technologies are below:

Enlist Duo® and Enlist One® herbicides provide superior

BREVIS® (metamitron) was developed with the aim to replicate the known effects of shade thinning on apple and pear trees and is the most effective Carbaryl substitute among all other thinning candidates. It combines a photosynthesis inhibitor and a commonly used fertilizer (Calcium formate). For the last 6 years ADAMA has been testing and improving the formulation of BREVIS® in a wide range of varieties, growing conditions and geographical zones (Europe, Americas, Asia, Africa, and Australasia). BREVIS® is now registered in 23 countries worldwide, with other key apple and pear markets to follow in the coming years. BREVIS® is an innovative product now patented in Europe and other countries globally.
Crop protection chemical products play a pivotal role in controlling the pests and diseases that infect and damage overall farm produce, and can further reduce the quantity and quality of food production. Excessive and unsuitable applications of crop protection chemicals, such as pesticides, herbicides, insecticides, and fungicides, among others, through traditional manual spraying, has resulted in an intensification of hazardous elements in the environment. Moreover, these crop protection chemicals demand high prices, leading to an increase in operational costs. Thus, incorporation of precision technologies for spraying of these chemicals has emerged as an ideal alternative to address the limitations faced by farmers, and to ensure ecological sustainability. This article covers the following points in detail about:

- Major applications, use cases, and downsides of UAV/drones in the agriculture industry.
- Stakeholder Analysis: Effect of UAV Based Delivery System on the Adjuvant’s Supply Chain

**Agricultural UAV Market by Applications**

The advancement of Unmanned Aerial Vehicles/Unmanned Aerial Systems (UAV/UAS) technology in a variety of industries, such as aerospace and defense, healthcare, retail, and others, is resulting in the proliferation of a number of uses across the globe, including the growing usage of UAVs/UAS in agriculture. These UAVs, in conjunction with image data analytics, are being widely used in the agriculture industry.

The agriculture industry has become a favourite among interested businesses and consumers of drones, and is expected to witness a sharp uptake of drones in the next 5-10 years. There are various ways in which UAVs are effectively reshaping and assisting the overall crop life cycle, based on their imaging, real-time data gathering, processing, and analytical capabilities, including:

- Precisely tracking and assessing the growth of crops and providing data about inefficiencies and deficiencies, as well as bacterial or fungal infections, and ensuring better crop management.
- Identifying areas of the farm which are dry, less irrigated, and need improvement, with the help of sensors, combined with UAVs

**Market Consolidation**

Companies are expected to merge, acquire, or partner to consolidate drone business solutions i.e., end-to-end solutions including hardware, software & services.

**Counter Drone Solutions**

Rising need to protect critical infrastructure and ordinary people from malicious drones is expected to fuel advancements in anti-drone technology and increased awareness about drone threats.

**Drone-as-a-Service**

Aging for affordable drone solutions, an increase in number of service providers for drones is expected thus lowering the entry costs associated with the drone technology.

**Artificial Intelligence**

Early AI driven drone solutions, especially for data analysis, aerial mapping & imaging is expected to drive the drone industry for autonomous solutions.

**Business Expansions**

Companies are expected to expand their business solutions across end-user industries. Internal teams shall also expand to manage large data & workflows.

**Regulations**

As the drone industry matures, formidable advancements in strengthening the regulations across the globe is expected. Major developments from FAA in the U.S. and EASA in Europe is being speculated.

Even in Africa, some 26% of the countries have stringent regulations governing the use of UAVs. Countries such as South Africa, Mauritius, Rwanda, Morocco, and Tanzania, among others, have successfully deployed UAVs for inspecting crops. In Morocco, UAS is used primarily for efficient application of crop protection chemicals. Les Domaines Agricoles, the largest Moroccan agribusiness, is one such company, which is utilizing UAV technology and image data analytics to ensure effective fertilization.

**Stakeholder Analysis - Effect of UAV Based Delivery System on the Adjuvant’s Supply Chain**

UAV/Drone providers effectively contribute a large value to the entire crop supply chain. Spraying of crop protection chemicals for disease, weed, and pest control is currently one of the emerging applications of drones in the agriculture sector. Drone manufacturers are expanding their market capabilities in this industry by partnering with various farm cooperatives and agriculture consultants.

Farmers use real-time information extracted with the usage of UAVs to plan their cropping cycle, and also for better decision making. Though the initial cost of implementation is high when compared to the benefits/returns received from this technology, UAVs as a viable technology is a justified investment.

Adjuvant manufacturers and companies providing crop protection chemicals can reduce wastage of their stocks and pre-plan accordingly through this data-driven approach.

Credit and insurance companies play an important role in the crop cycle, considering that majority of farmers’ livelihoods are largely dependent upon farm produce. Crop insurance protects farmers against any form of loss caused by crop failure, while credit institutions provide much-needed credit to them, to purchase technologically advanced products and utilize their efficient inputs.
By analyzing the real-time information generated by UAVs from the field, these companies can judge the credit worthiness of farmers and pay out monetary compensation with a better degree of reliability.

Agronomists and distributors operating in the market can also use extracted crop indicators and harvesting schedules to plan their distribution schedules and prevent losses.

### Companies Producing Adjuvants Compatible with UAV Applications

Adjuvants are primarily used in the agricultural industry to improve the performance of insecticides, pesticides and herbicides, which further improve the effectiveness of the crop protection chemical and help in providing better distribution and drift reduction. As per a report by BIS Research, the global agricultural adjuvants market is expected to grow from $2.8 billion in the year 2016 to $3.6 billion by 2021 at a CAGR of 5.5% from 2016 to 2021. Companies such as Adjuvant Plus Inc., ORBO AGRI, Helena Chemical Company, Wilbur-Ellis Company LLC, Solvay AG, Nufarm Ltd., Momentive LLC, Akzo Nobel Inc., BASF SE, Evonik Industries, and Elkem Silicones, are the key players operating in the agricultural adjuvants market.

#### Table 1: Adjuvants Compatible with UAV Application

<table>
<thead>
<tr>
<th>Adjuvant Name</th>
<th>Manufacturing Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silwet Low Drift Adjuvants</td>
<td>Momentive Performance Materials Inc.</td>
</tr>
<tr>
<td>AgRHO Aero-mate 320</td>
<td>Solvay S.A.</td>
</tr>
<tr>
<td>Malfix</td>
<td>Beijing Grand AgroChem Co., Ltd.</td>
</tr>
<tr>
<td>TIS 331</td>
<td>Jiangxi Tiansheng New Materials Co., Ltd</td>
</tr>
<tr>
<td>Pineye Emulsion</td>
<td>Foreverest Resources Ltd.</td>
</tr>
</tbody>
</table>

### Downwards of UAV Delivery System for Spraying Purposes

One major downside of deploying UAVs on farms for spraying or other purposes is the exceptional high cost of fully equipped UAVs, including sensors, radars, and related hardware and software. The high prices further increase when combined with the cost of acquiring technical skills and knowledge of piloting UAVs. Though cheaper UAV options are also available, these are primarily ill-equipped and inadequate for farming operations. In the majority of cases related to UAV equipment, increases in the performance directly proportional to the rise in prices.

### Benefits of Using UAVs for Agricultural Spraying

- **Increased Efficiency:** UAVs can cover large areas quickly, reducing the time spent on spraying and allowing for more effective coverage.
- **Improved Accuracy:** Precise targeting of specific areas can be achieved, reducing waste and improving the effectiveness of the spray.
- **Cost Savings:** Reduced labor costs and time savings can result in significant cost reductions.
- **Environmental Benefits:** Minimized drift can reduce the impact on non-target areas and improve overall environmental protection.
- **Data Collection:** UAVs can collect valuable data for decision-making, such as crop health and yield assessment.

### Challenges of Using UAVs for Agricultural Spraying

- **Regulatory Issues:**遵守严格的法规，确保安全操作。
- **Technology Limitations:** Limited by weather conditions and the precision of the spray.
- **Rural Infrastructure:** Requires appropriate infrastructure to support the operations.
- **Cost:** High initial costs and ongoing maintenance.

### Conclusion

The integration of UAVs in the agricultural sector has substantial potential for increased productivity and efficiency. However, the successful implementation of this technology requires careful consideration of the benefits and challenges, ensuring that the technology is used responsibly and effectively.
Introduction

Nanotechnology has the potential to deliver novel products to improve the performance of vistas, especially in agriculture and allied sectors. According to TERI’s press release entitled, “Are Natural Alternatives to Pesticides and Fertilisers by Nanotechnology Safe?”, various industries, from biotechnology, agrochemicals, pharmaceuticals, and health, as well as the food sectors, seem to be on firmer footing to use the cutting edge technology using nanoscience. Considering its wide range of uses, the global nanotechnology market is likely to develop at a CAGR of around 17% during the forecasted period of 2019-2024. This will provide a great opportunity for research institutes to develop and collaborate with industry and stakeholders to seek innovations in the fast-growing market, which would garner enormous revenues on the back of commercialization of the technology. However, nanotechnology is a multidisciplinary branch of science and needs groups of experts from several disciplines to deliver complete solutions to varied problems to allow it safe, efficient and cost-effective commercialization.

In terms of agriculture, nanotechnology represents a new frontier by offering potential applications in the delivery of nanofertilizers and nanopesticides, jointly referred to as “Nanonutrifights”. This deconstruction pattern of agronomic nanotechnologies has not only revolutionized agriculture with innovative nutrients, in the form of nanofertilizers (NFs), but also protects plants from phytopathogens. According to leading R & D analyses, research in agricultural nanotechnology applications has been on-going for much of a decade, searching for solutions to several agricultural and environmental challenges, such as sustainability, improved varieties, and increased productivity. Several institutes have shown the growing trend of both scientific publications and patents in agricultural nanotechnology, especially for disease management and crop protection. The nano-based delivery system for delivery of “Nanonutrifights” will offer a very cost-effective approach, with enhanced efficacy of active ingredients. Nano-based system in agriculture attempt to reduce the dose of active ingredients, minimise nutrient losses and increase yields through optimised water and nutrient management.

Problems with existing technologies and corresponding solutions

Agrochemicals are the chemical products composed of active ingredients that are used in agriculture as fertilizers and pesticides, to enhance the productivity of plants and management of plant diseases, respectively.

The disproportionate use of agrochemicals in high concentrations has led to the contamination of soil and groundwater by entering in the food chains, causing hazards to humans and animals. In addition, the runoff (or leaching from the soil) of agrochemicals into water resources can cause an adverse impact on the life-cycle of fish and other aquatic animals.

There is a large list of hurdles associated with conventional pesticides, such as non-biodegradability, resulting in long time persistence of pesticides in the field; frequently drift away (due to wind or air convection arrays) from the targeted field; high doses required because more than 30% of effective doses leach out from the soil; off target applications that contaminate much wildlife. Furthermore, conventional agrochemicals might not be helpful under these circumstances, as these have become expensive due to high energy requirements and being environmentally unsafe (Figure 1).

To address these limitations, the exploitation of the nano-based delivery system could be a promising alternative for sustained release of agrochemicals, to maintain the desirable activity and alleviate the potentially damaging impacts on the environment.

Recent translational innovations in the field of nanotechnology have transformed the world with distinctive nanomaterials, such as “Nanonutrifights”, and increased growth and productivity of crops. These forefront applications require the appropriate chemical functionalization of nanoparticles with organic molecules, or their absorption in an appropriate polymer matrix for sustained release. The polymer based nanocomposites material is a ground-breaking product, offering nanofertilizers dispersed in the matrix of polymers, and has received much attention recently. We have developed biodegradable and biocompatible chitosan-metal nanocomposites with enhance prolonged antimicrobial activities of metals (copper, silver and zinc oxide nanoparticles) and lower toxicity toward mammalian cells. Various attempts have been made to improve the antimicrobial activity of active ingredients, such as structural modification, adjustment of molecular factors, and forming complexes and their sustained release using nano based delivery systems. In practice, agrochemicals have been modified with the help of nanotechnology as “Nanonutrifights”, which are considered alternative routes to conventional fertilizers and pesticides.
The National Centre of Excellence in Nanotechnology for Agriculture and Environment and National Facility for Toxicology, Life Cycle and Regulations at TDNBC, supported and funded by the Department of Biotechnology, India, is committed to sustainable activities and practices to reduce environmental hazards of agrochemicals, which is one of the globally defined challenges, and engaged in various research activities, such as synthesis of nanopesticides and nanofertilizers, and their encapsulation using eco-friendly nanomaterial with prolonged activities, providing benefits to the plants beyond basic nutrition. In addition, TDNBC is developing smart delivery systems loaded with nano-forms of iron and zinc, primarily focusing to reduce the loss of active ingredients in conventional deliver systems due to volatilization or chemical reactions, microbial degradation, etc. Developing such nano-carriers can contribute to minimizing these losses. Furthermore, we have developed plant nutrients from industrial waste and will be the initiator to offer such an innovative approach towards providing sustainable solutions in agriculture around the globe. Also, we are participating in advanced research by developing more stable "nano emulsions" of pesticides having increased efficacy with lower application rates and controlled release.

Future development prospects

In order to improve the prevalent properties of agrochemicals, interactions between agrochemicals and plants can provide vital clues for the development of the translational technology, which can further generate significant benefits to farmers by improving field performance and reducing input expenses, not only in terms of cost, but also by reducing application losses. In the agrochemical sector, there are two main key players, industries and research institutes. Research institutes have robust capabilities to develop "nano-actives" or "nano-formulations" and industries typically deliver the product from research laboratories to the market. Moreover, both players can progress effectively and find better solutions for sustainable agriculture with nanotechnology.

We have also been developing next generation agro-nanoproducts, such as nano fertilizers, nano-pesticides and nanocarriers, with their complete life cycles, toxicity and regulatory assessments for agricultural use and increasing our research and market capabilities for ongoing growth in the agricultural field. There are various methods and technologies that have been developed by TERI-Deakin Nanobiotechnology Research Centre (TDNBC) for increased production, market access, and promoting sustainable farming practices. TDNBC is looking forward to creating collaborative research platforms which will be ready to translate its knowledge base at the grass root level, together in a coordinated fashion. The collaboration between TDNBC, TERI, New Delhi and industrial partners will create solutions in sustainable agriculture world wide using nanotechnology.

The TERI-Deakin Nanobiotechnology Research Centre (TDNBC) offers to join in and support the government’s vision to promote and assist further in implementing innovation and translational research, said Alok Adholeya, senior director (sustainable agriculture) at TERI, New Delhi, India.

Vision

Research in frontier areas of precision and smart agriculture, through innovative disruptive nanotechnology, might be the most promising step which may replace hurdles of existing agrochemicals. Understanding the development of these technologies and their applications, as well as public acceptance and societal impact in the coming era, will be crucial in bringing nanotechnology to the market to provide better and more sustainable solutions.

About TERI

The TERI-Deakin Nanobiotechnology Centre (TDNBC) was established in 2011 by The Energy and Resources Institute (TERI), one of country’s leading think-tanks, in collaboration with Deakin University, Australia, with the directive of developing ground-breaking nanobiotechnology centred solutions to address current challenges in the field of agriculture and environment. Conjointly supported by both organizations, the Centre aims to take global platforms through nanobiotechnology interventions in agriculture, environment, and energy, by developing multidisciplinary methodologies, tools and technologies.

Considering the importance of translational research in agriculture and environment, the Centre is uniquely poised to develop disruptive technologies using biocompatible nanomaterials. Such events are being brought together through strategic alliances with Deakin University and partners worldwide.
Aided by a favourable regulatory climate, as well as by concerns about conventional pesticides, the biopesticide market continues to grow. The global market is projected to grow from USD 3.0 billion in 2018 to USD 6.4 billion by 2023. Alongside the increased use of biopesticides (and other bio-actives used for agriculture, such as plant growth regulators and bio-stimulants) have come developments of more effective Integrated Pest Management application methods which take into account the health of the wider ecosystem and of the possible environmental impact of using control methods. However, with a total pesticide market (i.e. including conventional chemical pesticides) of around USD 56 billion, there remains considerable potential for further biopesticide growth.

The definition of biopesticides is not standardised but they are usually defined quite broadly and include the following general categories:

- **Macroorganisms** (e.g. insects, nematodes and other organisms that predate on pest species)
- **Microorganisms** (e.g. bacteria, fungi and viruses that kill or inhibit pesticides via a number of mechanisms)
- **Naturally derived biochemicals** (such as pesticides or enzymes) or other biological extracts (such as natural oils).

As with conventional pesticides, biopesticides must be formulated to provide a usable product that performs according to customer needs. The main functions of formulation are:

- To provide a finished product which is stable during manufacture, storage and use;
- To provide a product which is convenient to handle and to use in the application;
- To ensure that the full potential efficacy of the active ingredient is realised and that its delivery for maximum effectiveness is ensured;
- To ensure that the product can be used in a way that is safe for the user and the environment, and that it complies with regulatory requirements;
- To provide a robust process by which the finished product can be manufactured and packaged with a low level of manufacturing defects.

So where do the challenges of biopesticides lie, and do these challenges present any barriers to their further growth? Taking the category of naturally derived biochemicals and biological extracts first, these can essentially be formulated in a similar way to conventional synthetic chemical actives. The main additional challenge is that these compounds tend to be less chemically and physically stable than synthetic compounds. Peptides and enzymes, for instance, are prone to denaturing when exposed to heat and may readily degrade in acidic conditions. Therefore, for instance, it may be necessary to use formulation technologies, such as microencapsulation, to protect and deliver the active ingredient effectively or to include a UV-stabiliser to protect the active ingredient against photo-degradation.

In all cases, one very critical task is to ensure that any co-formulants used (e.g. surfactants, oils, solvents, carriers, binders, fillers, humectants, preservatives, etc) are chemically compatible with the active ingredient. Stability apart, however, actives in this category of biopesticides can be formulated similarly to synthetic pesticides. The formulator then needs, first, to consider the key physical properties of the active ingredient when selecting the formulation type, e.g.:

- **Water-soluble actives** may be formulated as soluble liquid concentrates (SL) or soluble granules (SG);
- **If a liquid product is desired, water-insoluble actives may be formulated (with an oil if necessary) as emulsifiable concentrates (EC), oil-in-water emulsions (EW) or microemulsions (ME);**
- **Active ingredients which are sold at room temperature can be formulated as water-based suspension concentrates (SC) or may be combined with co-formulants to produce water dispersible granules (WG) or wettable powders (WP) which will disperse readily in a spray tank. If a fine particle size is required, usually only those actives which are heat-resistant and relatively high-melting can be milled before formulation;**
- **Actives which are sold but are water-sensitive can be formulated as oil dispersion (OD) formulations which then require further emulsifiers in order to disperse the oil phase in the water of the spray tank;**
- **As mentioned earlier, actives which need to be protected in some way or where the release needs to be controlled can be formulated as microcapsule suspension (SC) formulations.**

However, the formulator has to consider the categories of biopesticides based on living organisms very differently from the naturally derived bio-chemicals described above. In the case of microorganisms such as bacteria, the objective is usually to ensure that the active organism is kept alive but in a dormant state during manufacture and storage, but on application it must be viable to then reproduce and become effective when applied to crops.

If the organism is not dormant in the formulation, then there is a danger that the culture will rapidly reproduce and consume any nutrients present and die out while still in storage. In addition, a living and growing culture can produce undesirable by-products, gas and odour during storage. For this reason, the simplest approach is often to reduce the water activity of the formulation to a low level, so that the organism will not reproduce on storage. Prior to formulation, the starting point is normally a water-based suspension of microorganisms. This suspension can be dried by methods, such as spray drying and freeze drying, in a way that does not cause heat damage. Then, solid final formulations with a low moisture content, such as granules (WG, GR) and powders (WP, DP), are often preferred. Additionally, to ensure initial microbial growth on application, nutrients such as carbohydrates may be added to the formulation.

On top of these considerations, the compatibility and stability of microbial actives need to be considered in the same way as for biochemical and synthetic chemical pesticides. So, the co-formulants used need to be balanced, with aggressive solvents and extremes of pH being things to be avoided.

Protection of microorganisms during formulation and afterwards can be enabled by the use of encapsulation technologies. There is a huge variety of possible methods to do this, here are just two interesting examples:

- **The popular microbial biopesticide Bacillus thuringiensis (Bt) can be encapsulated, using a technique called Pickering emulsions, whereby emulsions are stabilised by solid particles.**
- **The UV resistance of the fungal bio-insecticide Beauveria bassiana has been improved by the use of feruloylated soy glycerides (FSG), which were subsequently encapsulated in starch.** Additionally, soluble lignin was used as a spray tank adjuvant to protect against UV. Again, the use of environmentally benign co-formulants is favourable for the safety profile of biopesticides.

Increasingly, bio-derived active ingredients are being formulated, together with conventional synthetic pesticides. One example of this is REGEV™ from STK. The two actives are a biofungicide based on a plant extract (Tree Oil or TTO), as well as difenconazole, a conventional synthetic fungicide. The relevant patent claims that the TTO is delivered in the form of an oil-in-water emulsion. The patent also claims the use of TTO with a large number of fungicides – so perhaps further new mixes are to be expected.

Biopesticides and conventional pesticides are also being formulated together in seed treatments. Poncho®/VOTiVO® (now being marketed and sold by BASF) combines the systemic insecticide clothianidin with Bacillus firmus I-1582 in a seed treatment. The clothianidin is immediately absorbed by the roots and the Bacillus firmus I-1582 forms a barrier around the seed. It is claimed that this protects against up to two generations of nematodes.

In conclusion, the potential incompatibilities between conventional synthetic active ingredients and microorganisms, as well as other bio-actives, can clearly present challenges to the formulator - who may also have to deal with issues, such as UV-stability and the delivery of microorganisms. In addition to dealing with the usual challenges of efficacy and stability that the formulator has to handle for all kinds of crop protection products, it is clear that formulation will have a very significant role to play if the market for effective bio-control products is to continue to grow at a rapid rate.

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Stepan: Next Generation Compatibility Agent for Today's Complex Tank Mix Systems

Over the past couple of decades, it has become increasingly common, if not necessary, to combine multiple crop protection products into one spray application. Beyond the obvious advantages of time savings and reduced application costs, this strategy combats the ever-present challenge of pest and pathogen resistance by employing multiple modes of action (MOA).1 Leading crop protection companies implement MOA by combining several active ingredients into one formulation. In cases of single-active ingredient formulations, growers will tank mix multiple crop protection products to achieve the same desired MOA effect.

Regardless of approach, today, spray tanks increasingly contain more active ingredients than in years past, leading to a delicate system between tank partners. Further complicating matters, growers will often use liquid fertilizer as a carrier in place of water to gain even more efficiency. Given the complexity of modern crop protection strategies, it's not surprising to see a rise in compatibility issues surrounding tank mixtures.

These incompatibilities can occur between active ingredients, but more commonly arise when formulations are diluted into liquid fertilizer, where hydrophobic organic molecules and water-soluble salts are at odds with each other. These incompatibilities can present in many forms, including the formation of particles or gels that rapidly settle out of suspension, separation of the mixture into layers, or excessive foaming. As one might imagine, spraying an incompatible mixture can result in a loss of efficacy due to uneven distribution, poor performance, or crop injury.2, 3 In severe cases, these issues can clog sprayers that lead to equipment shutdown and cleanout.

In the crop protection industry, compatibility agents are used to combat stability issues before and/or after they arise. Our research has determined that more than 75% of commercial compatibility agents use phosphate esters, a majority of which are based on nonylphenol ethoxylates (NPEs).4 NPEs have been the backbone of compatibility agents for decades and remain dominant in the market due to availability and low cost. However, while NPE-based compatibility agents are effective in simple tank mixtures, they have marginal performance in complex systems. As incompatible systems have become more challenging, innovation has stalled in the development of new compatibility agents that can meet the demands of tank mix systems today. Furthermore, NPEs have well-known environmental and health concerns, resulting in their use being slowly phased out across the agrochemical industry.

Considering today’s complex nature of tank mixtures and regulatory concerns surrounding NPEs, Stepan saw a need to develop a next generation phosphate ester compatibility agent. We believe the market has yet to take full advantage of the immense potential phosphate esters offer, given the ability to tune monoester/diester ratios, select from a wide range of hydrophobes, and vary the degrees of ethoxylation (Fig. 1). Thus we launched an initiative to study these parameters in detail to find the optimal phosphate ester, then leveraged our experience in formulation development to further enhance performance with additional additives to produce a top market compatibility agent.

With access to a wide array of hydrophobes, we synthesized and screened more than 70 unique molecules, identifying trends for each parameter. Each iteration was evaluated in nine incompatible systems containing a formulated pesticide and fertilizer. Our screen included a variety of formulation types, including emulsifiable concentrates, suspension concentrates, and soluble liquids. Performance was assessed based on the number of incompatible systems a phosphate ester was able to improve.

The first parameter that we studied in detail was the phosphate ester’s monoester/diester ratio. Phosphate esters with either high monoester or high diester content were evaluated across multiple carbon chain lengths and moles of ethylene oxide. The results demonstrated that high monoester containing phosphate esters were equivalent or better than their high diester counterparts across all systems, regardless of hydrophobe or moles of ethylene oxide (Fig. 2). This suggests that the more hydrophilic nature of monoesters enhances solubility in high electrolyte environments. For the rest of the study, we chose to work with only high monoester phosphate esters.

Next, we studied the effect of ethoxylation across various carbon chain lengths. Performance was found to improve when a lower degree of ethoxylation was employed and was not dependent on carbon chain length (Fig. 3). As moles of ethylene oxide were increased, the effect on compatibility became more variable based on a specific incompatible system and phosphate ester molecule. There appears to be a minimum degree of ethoxylation required for water solubility and broad-spectrum performance, beyond which performance begins to deteriorate as ethoxylation levels become too high.

Figure 1. Reaction schemes of phosphate esters.
Last, we evaluated a range of carbon chain lengths at multiple degrees of ethoxylation. An optimal carbon chain length was identified that displayed peak performance for all ethoxylation levels (Fig. 4). Combined, these trends led to a final phosphate ester with high monoester content, a low degree of ethoxylation, and an optimized carbon chain length.

With our top performing phosphate ester defined, we leveraged our formulation expertise and extensive portfolio of inerts to further enhance the compatibility performance. The phosphate ester was paired with an array of secondary components, including emulsifiers, wetting agents, and other compatibility aids. Light scattering measurements were implemented to track instability over time and identify the most stable formulation candidate (Fig. 5). Ultimately, optimized secondary components were identified and found to significantly increase the performance of the phosphate ester, leading to our new tank mix compatibility blend, TOXIMUL® CT.

TOXIMUL CT was tested against commercially available compatibility products (Fig. 6). The commercial products all contained phosphate esters as their primary component, many of which were NPE based. The results demonstrate that TOXIMUL CT provided superior compatibility performance over current commercial solutions in high electrolyte systems. For situations where incompatibilities between active ingredients were observed, we also saw an improvement using TOXIMUL CT. For example, compatibility is significantly improved in an atrazine/paraquat system with TOXIMUL CT over competitive products (Fig. 6b).

In conclusion, TOXIMUL CT is an excellent option for solving difficult compatibility issues over a wide variety of tank mix systems. In the design of this new blend, we evaluated more than 70 unique phosphate esters and screened more than 2,000 incompatible systems to find the best product. TOXIMUL CT is an innovative solution that can help meet the demands of today’s increasingly complex spray tank mixtures.

References:

Figure 5. Light scattering results for the top performing phosphate ester vs. formulated blends for two incompatible systems. A rise in light scattering over time indicates instability in the form of separation, precipitation, or gelling.

Figure 6. Light scattering results for compatibility products for two incompatible systems (A). Atrazine/paraquat tank mix with TOXIMUL CT and commercially available products (B).
Oil dispersion (OD) formulation is an emerging formulation in Ag industry, which is claimed as environmental friendly, better pesticide efficacy than water-based formulation. Because the continuous phase is oil, like methyl oleate, methyl soyate, it shows high affinity with plant leaves, thus providing better spreading, wetting and penetration performance. However, the existing OD products have common issues of inadequate long-term storage stability, phase separation and caking in the bottom after several months storage. This hinders the booming development of OD formulation. Therefore, it is of high importance to explore high performance adjuvants of emulsifier, dispersant and thickener, exclusively used in OD formulation, promoting the industry technology progress.

Dow possesses rich product portfolios in emulsifiers and dispersants. How to develop the high performance products to address industrial challenges is our high priority these years. In this paper, high performance OD adjuvant development process had been described, followed by formulation preparation and performance evaluation. Currently, POWERBLOX™ OD products is ready to deliver to the market for formulation trial and performance validation.

**Lego Unit Approach**

It is well known that the OD formulation is a complex system, even for adjuvants, including wetting agents, emulsifiers, dispersants and thickeners. If all of the factors are considered together in the design of experiments, it will generate a huge amount of experiments and heavy workload. In order to accelerate product development progress, Lego unit approach was utilized to reduce design parameter as shown in Figure 1. At the initial stage, we investigated the performance between thickener and oil and the performance between emulsifier and oil, to select proper thickener and emulsifier. And then, the thickener and emulsifier in oil were fixed as the base system to evaluate the compatibility and stability of screened dispersants. Finally, the active was incorporated into above system to prepare OD full formulations and evaluate their storage stability. The technical hypothesis for this approach is:

- Thickener plays a dominant role in oil phase thickening. The better thickening effect, the higher viscosity of oil phase, little related to active and other additives.
- Emulsifier is decisive to emulsion quality and stability when OD formulation is diluted into water.

**Thickener Performance Evaluation**

Methyl oleate is the largely used oil phase in OD formulation. In the following experiments, the methyl oleate was used as received from Wilmar. Various kinds of thickeners from different producers, more than 30, were collected to evaluate their thickening performance to methyl oleate, including organic, inorganic and organic-inorganic combination type. The comprehensive performance was tested, in term of oil compatibility, thickening effect, dispersing effect and cost effectiveness. It revealed that organobentonite was still the best choice in the market. The recommended dosage was 2.0-4.0 wt%.

**Emulsifier Performance Evaluation**

In the application, OD formulation needs to be diluted into water firstly, prior to spraying. Therefore, emulsifiers play a critical role to get the high quality emulsion, thus affecting drug efficacy. Emulsifiers with various HLB values were selected to evaluate their effect on initial emulsification performance and emulsion stability over time. The emulsifier dosage was fixed at 10wt% in methyl oleate and the dilution was 200 times in water. When oil phase was added into water phase, turned the mixture upside down for 20 times for further emulsion stability observation over time. As shown in Figure 3, the performance of one series of emulsifiers with HLB value from 8.5-13.6 demonstrated that the higher the HLB value, the better the initial emulsification performance and the emulsion stability. However, high HLB value generally means high polarity, it may have compatibility issue with oil phase, which is of relatively low polarity.

Span and Tween were taken as starting emulsifiers to mix in different ratios to get various HLB value emulsifier mixtures, which were used to study the compatibility with methyl oleate. As shown in Figure 4a, with the increase of HLB value, the compatibility between emulsifier mixture and oil phase became worse and worse, from transparency and homogenous to turbid. In Figure 4b, the performance of the screened Dow' emulsifier mixture with high HLB value at 12.0-13.0 showed excellent compatibility with oil phase with transparency and homogenous appearance, which resulted from the specially designed structure. Besides the good compatibility, excellent emulsification performance is the final target. It was shown in Figure 4 c1, the mixture of oil and emulsifier with mediocre emulsification ability was added into water, as a result, the oil droplets couldn’t be emulsified spontaneously, but fell to the bottom still as oil droplets.

When the mixture of Dow’s emulsifier and oil phase was dropped into water phase, the oil could be emulsified quickly with fine emulsion and excellent stability.

**Dispersant Screening and OD formulation Development**

Dispersant is used to disperse and stabilize pesticide particles, providing OD formulation long-term storage stability and ensuring sufficient shelf life. After thickener and emulsifiers were confirmed, dispersant was screened firstly by verifying its compatibility with oil and then by formulation development and optimization via altering the ratio of each components. As mentioned above, the components were complex in OD formulation with wide changing range, it was of high workload and time consuming. Dow high throughput platform could prepare a large amount of formulations in short time, facilitating to performance comparison and formulation optimization. Through scientific experiments design to get a lot of formula, the high throughput process was utilized to prepare target formulations as seen in Figure 5, more than 200 formulation within 1 week. Followed by, the excellent formulation could be screened out, on the
basis of performance evaluation.

Taking 2.5wt% penoxsulam OD formulation development as example, 12 formulation had been selected out of all of the designed experiments, due to superior thermal storage stability to benchmark (seen in Figure 6). After 2 weeks thermal storage, benchmark product (commercially available product and used as received, non fresh sample) had around 8% phase separation. For our developed samples, there was no phase separation by naked eyes, keeping homogeneous system.

In order to differentiate the formulation performance difference caused by dispersant, accelerated stability testing method combining centrifugation and transmitted light scanning was used for performance evaluation to the formulations with good thermal storage stability. As seen in Figure 7 of each graph, the X axis stands for sample bottle height, the left is bottleneck and the right is bottom of bottle. And the Y axis indicates the transparency of the sample in the bottle. The lower the transparency, the better the sample stability. Moreover, the more the high transparency, the better the sample stability. The results demonstrated that the number 12 sample showed best stability, thus providing an optimization adjuvant package to target formulation.

At the same time, to know more clearly the detail difference among each formulation, instability index was introduced to quantitatively measure formulation stability. Instability index is a specific value combining with Stokes’ Law and Lambert-Beer’ Law, demonstrating the relative value of the sum of transparency change to the maximum clarification during centrifugation, with the value range of 0-1. For the same active particles (same density) in close viscosity, the lower instability index, the better formulation stability. It was seen in Figure 8, the instability index of all of evaluated formulations were not so high, and the value of number 12 was the lowest, indicating the best stability.

In a word, the thorough process had been built-up on adjuvant formulation development, formulation preparation and performance evaluation. The explored high throughput platform for OD formulation development process

![Figure 5. High throughput platform for OD formulation development process](image)

![Figure 6. 2.5wt% penoxsulam OD formulation thermal storage stability after 2 weeks](image)

![Figure 7. Accelerated stability testing](image)

![Figure 8. Quantitative index for stability](image)

The agricultural market is under increasing pressure as consumers ask for food containing lower, or no amounts of residual chemicals, but at the same time growers need to prevent the development of pathogens and pests resistant to active ingredients. Regulators demand less agrochemical input and some chemical pesticides have already been phased-out.

Well-known in the agrochemical market, Surfactants are used in formulations and as tank mix adjuvants. The benefits of adjuvants are important in plant protection products from pesticide formulation to storage, tank-mix dilution, spraying, targeting and finally acting on the pest. In water-based formulations, their main task is to decrease surface tension resulting in better wetting of the dispersed particle in water and more stable formulations. In oil-based formulations, emulsification properties support the quality of the emulsion ensuring higher stability and lower droplet size. In tank mix dilutions for all kinds of formulations, surfactants prolong physical stability as they reduce the surface tension of water. Targeted delivery is the main purpose of surfactants during spraying, which enhances efficacy and decreases the active amount needed. Targeted delivery is achieved by: 1) reducing driftable particles 2) enhancing adhesion and retention of spray droplets on the plant. 3) Improving uptake and penetration of active ingredients, and 4) increasing rain fastness.

However, regulatory pressure is rising with additives like NPE based solutions phased-out globally. With the agrochemical market demanding innovative, more sustainable additives, Evonik has developed benign surfactants which enable a more environmentally friendly plant protection.

New adjuvants that comply with eco-toxicological, safety and sustainability criteria provide solutions to support the plant protection industry. Evonik is introducing sustainable and biodegradable adjuvants in the following four classes: Wetting agents and multifunctional additives based on biodegradable trisiloxanes, polyglycerol esters and sorpholipids.

Due to their chemistry, the way these novel surfactants work is different. Roughly speaking, the lower the surface tension of spray droplets the better adhesion and retention on the leaf. Water with 72 mN/m gives a strong bounce off of spray droplets. Trisiloxanes help to reach the lowest surface tensions and Evonik has developed readily biodegradable [method OECD 301 F, OECD 301 A] trisiloxanes based on a unique patented technology. The reduction of water surface tension down to 21 mN/m facilitates the best adhesion and retention of droplets on very difficult to wet surfaces. Due to their special phase behavior in water, they provide superspreading of water, solutions and dispersions to ensure the best coverage of contact actives on surfaces thanks to the contact angle of 0°. This also enables the highest biological efficacy. In contrast to other superspreading trisiloxanes, these biodegradable trisiloxanes have no ecotoxicological classification and are not dangerous goods for transportation.

BREAK-THRU® S 301 is soluble in water and many oils, so it can be used in all kind of liquid formulations and as a tank mix adjuvant to give excellent adhesion and retention of spray droplets. Commercially available products with living microbial actives rarely contain surface-active molecules, and alongside the low wetting and low dispersing properties of solid
formulations in water, can often provide low and inconsistent field performance. BREAK-THRU® S 301 can be used as a carrier liquid in dispersion concentrates for increased shelf life of living microbial products. As a tank mix additive, BREAK-THRU® S 301 leads to a better dispersion of microbial actives in the spray solution, and to excellent wetting in the application, helping increase the efficacy of microbial-based pesticides.

**BREAK-THRU® SD 260** is developed specifically for use in WP – formulations for chemical pesticides or for biopesticides. The product is the first water soluble, solid trioxane to provide humectant properties, and to offer excellent wetting properties as it includes BREAK-THRU® S 301. The addition of 1 - 5% w/w BREAK-THRU® SD 260 to the powder or granules of biopesticides significantly increases the surfactant properties of the final tank-mix dilution. At a concentration of 0.1 w/w-% it reduces the surface tension of water to 22 mN/m and the humectant property supports the field efficacy of the microbes.

Unique readily biodegradable adjuvants based on polyglycerol esters and sophorolipids fulfill modern requirements for all types of plant protection products and consist of a natural carbon source. They reduce the surface tension of water down to 30-35 mN/m. Incoming droplets solutions with such surface tensions normally show a strong and fast receding effect from the contact line, often leading to bounce off and loss of spray droplets. The new action is based on the interaction of the hydrophobic emulsified droplets with the cuticle leading to a so called ‘pinning effect’ preventing the droplet receding from the contact line of the water droplets. These droplets also stick to the surface so retention is excellent. It’s well-known that polyglycerol esters and sophorolipids lead to a swelling of the cuticle wax which improves the penetration through the cuticle. This facilitates the uptake of lipophilic and hydrophilic active ingredients through the cuticle and epidermal cells (see Figure 1 and Figure 2). This physico chemical interaction of the bio-based molecules with the cuticle wax can be shown nicely with confocal laser scanning microscopy as reported previously [Haense, et. al. (2015) Polyglycerolester as Sticker Penetrant Adjuvant]. For systemic and contact active ingredients these products are well suited, and due to their hydrolytic stability these surfactants can be used for water-based and oil-based formulations.

**BREAK-THRU® SP 133** has a natural carbon content of 93%, is readily biodegradable and comes without a hazardous label. Its raw materials glycerol and fatty acids are derived from different vegetable oils. This polyglycerol ester-based product also provides excellent adhesion and retention of difficult to wet target species. Wind tunnel trials at the University of Nebraska have shown that BREAK-THRU® SP 133 reduces the amount of driftable particles due to an increase of the spray droplet size: the expanding water film is broken up directly after the nozzle, which induces bigger droplets that are less prone to drift. Less driftable droplets means not only a higher field efficacy, but also less harm to the environment.

**BREAK-THRU® SF 420** is a sophorolipid-based surfactant manufactured by the fermentation of rapeseed oil and sugar. This vegetable, not genetically modified feedstock is sourced in Europe. The yeast strain used is also a natural microorganism: Starmerella bombicola. It is a readily biodegradable biosurfactant with dispersing und wetting properties. Due to the special geometrical structure, BREAK-THRU® SF 420 is an excellent dispersant for metal hydroxides like Cu(OH)2 in water which makes it an excellent option for SL and nutrient SC formulations. Due to the more even distribution of, for example, copper spray solution on the foliage, it improves the control by fungicides. However, it was proven to also improve insecticide performance and enhance the activity, the speed of action and the duration of herbicides.

At the same time this multifunctional biosurfactant performs very well as a water soluble, low foaming tank mix surfactant by reducing the surface tension of water down to ≤ 35 mN/m. However, due to the novel mode of action BREAK-THRU® SF 420 provides excellent adhesion and significantly higher retention on very difficult to wet species. After drying the remaining film generates with rainwater a gel layer by a hydration effect of the polymeric sophorolipid. This results in excellent rainfastness (see Table 1 and Figure 3).

Taken together, all the features of our sustainable multifunctional surfactants help increase the biological efficacy of agrochemicals and biosolutions. This has already been proven in many field trials around the globe. BREAK-THRU additives enable microbials as active ingredients to have the lowest environmental impact, leading to a higher acceptance of these solutions by farmers and addresses the need of consumers for food with lower chemical residuals.

**Approvals for organic farming become more important, even for conventional farming, as it demonstrates the superior sustainability of the products.** Therefore, the possibility of getting these approvals is a key criteria for Evonik in the development of new additive products. BREAK-THRU® S 301 and BREAK-THRU® SP 133 are already approved for OMRI, and BREAK-THRU® SP 133 is additionally Fibi registered and thereby the first surfactant for the German speaking organic agricultural market.

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**Table 1: Evonik Cu-formulation: Copper hydroxide 383 SC**

<table>
<thead>
<tr>
<th>g/L</th>
<th>Ingredient</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>383</td>
<td>Copper hydroxide</td>
<td>Active ingredient</td>
</tr>
<tr>
<td>75</td>
<td>BREAK-THRU® SF 420</td>
<td>Dispersing agent</td>
</tr>
<tr>
<td>3</td>
<td>BREAK-THRU® AF 9903</td>
<td>Antifoam</td>
</tr>
<tr>
<td>3.3</td>
<td>NaOH (20% solution)</td>
<td>Neutralization</td>
</tr>
<tr>
<td>2.5</td>
<td>Xanthan gum</td>
<td>Thickener</td>
</tr>
<tr>
<td>50</td>
<td>Propylene glycol</td>
<td>Antifreeze</td>
</tr>
<tr>
<td>q.s.</td>
<td>Water</td>
<td>Solvent</td>
</tr>
</tbody>
</table>

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**Figure 1:** CLSM study of BREAK-THRU® SP 133 penetration of the pseudo-lipophilic pesticide mimic (RHODAMINE® B) into bean leaves [2 HAT 63 x mag.]. Near-surface horizontal and vertical cross-sections

| pure RHODAMINE® B Dye | 0.1% BREAK-THRU® SP 133 |

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**Figure 2:** CLSM study of BREAK-THRU® SP 133 penetration of the hydrophilic pesticide mimic (Oregon® Green) into bean leaves [2 HAT 63 x mag.] Near-surface horizontal and vertical cross-sections

| pure Oregon® Green | 0.1% BREAK-THRU® SP 133 |

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**Figure 3:** Effect on mean copper deposits (µg/cm²) retained on wheat, cabbage and bean foliage - Post Rain Analysis
Huntsman: Solvents as Solutions for Formulations

When a formulator begins a project on a new active ingredient, the appropriate solvent is one of the early considerations. Since many pesticide actives have aromatic characteristics, back in the 1960s, the formulator might use any number of aromatic hydrocarbons or halogenated solvents. As we began to understand the potential environmental and health impacts of various compounds, the field of choices naturally began to narrow. During the 1980s, N-methylpyrrolidone (NMP) became the choice for otherwise difficult formulations. Upon further study, however, it became clear that NMP was not the savior everyone had thought it would be.

The movement in the 1990s and 2000s to more environmentally responsible and, lately, to more sustainable ingredients, has changed the available choices. Paraffins are currently preferred if a hydrocarbon is needed, but they need help solubilizing aromatic actives. Aromatic hydrocarbons are still available, but with stricter regulations may not be a sustainable ingredient for the future, which leads them to be rarely, if ever, considered in a modern formulation. The future alternatives may very well be weaker solvents for the actives or not sustainable long-term.

The modern developer of a formulation to be used locally, regionally, or globally must consider an array of regulations that sometimes severely limit choices. The available choices are usually limited to a menu provided by regulatory authorities from which formulator must choose those solvents that may be compatible with the active. In addition, the other ingredients, such as wetting agents, compatibility agents and other ingredients, generally further narrows the available choices. Also, the company may have a particular solvent of choice for a particular class of ingredients.

The job of the solvent is to carry the active in liquid form in the container to primarily provide a stable environment for the rest of the ingredients. Solvents provide flowability and ease-of-delivery, two characteristics that make liquid formulations highly desirable.

The challenge is to choose the right solvent from the available menu. Modern solvents can include ingredients derived from both petroleum and biological sources. Biological sourcing is important for many companies, due to their environmentally responsible and sustainable credentials. Farmers, formulators and applicators around the world have understood, and integrated the need for environmental responsibility for many, many years, and so have naturally dialed into their thought and decision processes.

Since environmental factors are built into the choices by companies and governments, the primary key to making the right choice of solvent is driven by the core purpose of the solvent. The choice must be made from the available menu based on how well the solvent provides a stable liquid environment for the active and the other ingredients.

While solvents like paraffins and methylated vegetable oils (MSOs) are available, they tend not to solubilize the most difficult actives very well. In addition, MSOs can have temperature and other stability challenges. Other, more exotic choices may be available, but tend to be expensive. “Simple” tends to be best. “Simple” small molecules tend to have very low freezing points. Small esters with small side chains or groups tend to dissolve many ingredients well. Aromatic solvents tend to dissolve aromatic actives. JEFFSOL® AG 1700 solvent and JEFFSOL® AG 1705 solvent are two effective “simple” choices. Their aromatic character makes them compatible with various active ingredients. The simplicity of the molecules gives them a low freezing point with JEFFSOL® AG 1705 being able to remain liquid by itself down to -60 C.

When aromatics are not the answer, but rather a more polar solvent is needed to bring in polar molecules, the formulators are recommended to look at carbonates as an alternative. They are available in a variety of forms, such as JEFFSOL® AG 1555 solvent. JEFFSOL® AG 1555 solvent is both polar and has a high degree of biodegradability. Used in non-aqueous systems, JEFFSOL® AG 1555 solvent has been useful in a variety of formulations where NMP and other polar solvents may no longer be used.

Now, as ever, the choice of solvent is critical. However, with the environmental and toxicological limitations driven by today’s regulations, those choices are more and more limited. Choices of solvents may vary in the market, but “simple” solvents with low melting points can help with a diversity of performance needs, such as cold tolerance, viscosity and stability. Overcoming challenges such as these by using modern solvents, such as those mentioned above, will help bring success to your formulations.
Agrovista steps up marketing of spray application aids into Europe

Peter McDonald
Head of Commercial Strategy & Discovery Europe at Agrovista
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Figure 1. Agrovista’s Discovery products are trialled extensively across Europe

After two highly successful decades building a multi-million pound market around its range of Discovery spray application aids in the UK, agronomy company Agrovista is using its sector-leading expertise to accelerate its marketing drive into continental Europe.

Target regions include Central Europe, Russia, Ukraine and Turkey, which have the potential to greatly increase company revenues, says Peter McDonald, Agrovista’s Head of Commercial Strategy & Discovery Europe.

“Discovery products are an increasingly important part of Agrovista’s business, and the brand has the potential to become very significant.

“These application aids improve the performance of plant protection products. Pesticide efficacy is reduced by water quality, poor application and inadequate coverage, retention and uptake on the target surface. Discovery products overcome these challenges, improving the level of control and increasing yields.”

Many leading UK growers now use Discovery products to maximize the potential of their agrochemical applications. McDonald believes farmers in the target regions will soon be following suit.

“We have had a presence for some 10 years in north-west Europe, and two to five years in the target countries. European revenues have the capacity to be five times that of the UK, perhaps more in the longer term.

“Regardless of where they farm, growers are facing tight profit margins. They need to make use of every tool in the box to help them achieve maximum yields and returns.”

Comprehensive trials across continental Europe have demonstrated the value of Discovery products in improving the efficacy of plant protection products (Figure 1), underpinning findings from up to two decades of research work and commercial use in the UK and, more recently, northwest Europe.

“By enhancing the effects of agrochemical products, our Discovery range can deliver significant increases in yield for a relatively modest outlay,” noted McDonald.

“We believe they offer significant benefits at any time, and particularly when returns are being squeezed. Growers don’t have to take our word for it – they can see the impressive results the Discovery range has achieved in trials. These products are proven across a range of crops and climates.”

As legislation tightens and pest, weed and disease resistance increases, some active ingredients will disappear, while others will be subjected to tighter dose restrictions. “This strengthens the case for using Discovery products - growers need to extract maximum performance from remaining chemistry,” said McDonald.

Three products are spearheading the European campaign. Companion Gold, the most popular spray application aid in the UK, is a multi-functional adjuvant and pod sealant most often used with glyphosate. Remix is an additive that improves the performance of residual herbicides and Velocity is designed to improve the coverage and uptake of fungicides (see panel).

“Each Discovery product has completed a multi-year pan-European R&D screen to ensure efficacy,” said McDonald. “This comprises laboratory studies and high quality replicated field trials across a wide range of geographical locations, soil types, climatic conditions and crops. Physical chemical, environmental and regulatory studies are completed to ensure consistent product performance.

“We also put great emphasis on conducting quality trials with our distribution partners and respected research organizations in each country we market. And our ground-breaking spray application trials explore the relationship between plant protection product, application technique and tank mix additive, giving a unique insight into performance on farms.”

Discovery products are manufactured by Agrovista UK, which can trace its roots back 60 years. The business is part of Agrovista BV, a leading European organization in the field, itself part of the international Marubeni Corporation, which has representative offices and is well known in all of the countries where Agrovista is looking to expand.

“We work very closely with Marubeni in these new markets,” he added. “Most people will not have heard of Agrovista, but being part of Marubeni, prospective clients will know we are a reliable and trusted partner they will be comfortable doing business with.”

Discovery R&D

Each Discovery product is put through a multi-year pan-European R&D screen to ensure they perform to the optimum in all market locations.

Tests include laboratory studies and high-quality trials conducted at sites throughout Europe that encompass a wide range of soil types and climates, as well as key crops for different areas, such as cereals, maize, oilseeds, pulses, sugar beet and potatoes.

To ensure maximum performance, Agrovista has designed and developed its own self-propelled sprayers, enabling researchers to test products and methodology under replicated farm conditions.

Research is carried out and evaluated by Agrovista’s own trials team, universities, government research institutes and leading contract trials organizations.

In addition, Agrovista works in conjunction with the world-renowned Silsoe Spray Applications Unit to optimize practical spray advice.

Discovery range

• Spray application aids
• Tank-mixed spray additives and adjuvants
• Designed to enhance efficacy of plant protection products
• Targeted formulations, focused by pesticide requirements
• Improved spray application
• Supported by pan-European R&D program
• Comprehensive efficacy data to support use

Key Discovery products

Companion Gold is the perfect partner for glyphosate and can also be used as a pod sealant in oilseed rape and legumes.
This multi-function adjuvant is a tallow-amine-free formulation containing a blend of drift-reducing polyacrylamide polymers, pH buffers, water conditioners, antifoam agents and humectants.

Companion Gold has been proven over many years to significantly enhance the performance of glyphosate. More recent trials suggest those benefits could be even greater when using the new tallow-amine-free glyphosate formulations, which Agrovista trials suggest may be less effective at controlling grass weeds under challenging timings.

Remix is designed specifically to enhance the performance of residual herbicides. It contains a unique blend of highly refined paraffinic oil, hexahydric alcohol ethoxylates and long-chain fatty acids.

The product reduces spray drift, ensures even deposition of the spray over the soil surface and increases adsorption to soil particles, reducing crop effects while increasing residual weed control.

Over the past 10 years, the addition of Remix to a residual herbicide stack has improved black-grass control by 11% in Agrovista trials.

Velocity is designed to enhance fungicide application and efficacy in a range of crops. It also reduces spray drift, ensuring accurate spray deposition over the target surface.

Organosilicone surfactants ensure complete coverage, while humectants slow droplet drying. Fatty acid methyl esters improve penetration though the outer waxy layers of the leaves.

Results from eight fully replicated trials across Europe over a four-year period using the label dose have shown that adding Velocity can reduce fusarium levels by half, compared with straight fungicide when applied at the key early flowering spray timing.

Adding Velocity also allows spray volumes to be halved in certain situations without loss of efficacy.

* For further details on Agrovista’s Discovery range, please go to www.discovery-eu.com

The Discovery range

Roller - Provides even coverage and excellent crop safety
Velocity - Improve disease control and increase yields
Remix - Reduce drift & enhance deposition of residual herbicides
Companion Gold - 6 way mode of action adjuvant and pod sealant
KryptoN - Advanced foliar nutrition
Nelson - For use with Sulfonylurea and fop and dim herbicides
Stingray - ph buffer and water conditioner

Made in Britain and supported by a pan-European R&D programme, our targeted adjuvant and additive formulations improve efficacy and increase yields.

For more info: Tel: +44 (0) 115 939 0202 Email: peter.mcdonald@agrovista.co.uk www.discovery-eu.com
What is an adjuvant? How do they work?

- Adjuvant is a product that optimizes the efficacy of another, mainly: herbicides, insecticides and fungicides, and ultimately reduces limiting factors during spraying of Crop Protection (CP) products.
- Limiting factors for a successful application of CP products:
  - Climate/weather
  - Water quality
  - Specific CP management
  - Droplets
  - Sprayers
  - Etc.

Adjuvants offer solutions for farmers in three beneficial areas:

1. **Technical benefits**:
   - a. Limiting factors for successful treatment
   - b. Modern spraying:
     - i. Increasing application speed
     - ii. Reducing water volume (Figure 1)

   - c. Sufficient product effectiveness >> a.i (active ingredient) from chemical, fungicide, insecticide or herbicide products, such as the pH control of the treatment broth and water hardness.
   - d. Better CP treatment balance cost/ha vs effectiveness
   - e. Better applications focused on pest/diseases targets
   - f. Less CP product waste:
     - i. Reduced drifting
     - ii. Reduced evaporation effect
     - iii. Reduced soil loss

2. **Economic benefits**:
   - a. Better applications focused on pest/diseases targets
   - b. Less CP product waste:
     - i. Reduced drifting
     - ii. Reduced evaporation effect
     - iii. Reduced soil loss

3. **Environmental benefits**:
   - a. Better applications focused on pest/diseases targets
   - b. Less CP product waste:
     - i. Reduced drifting
     - ii. Reduced evaporation effect
     - iii. Reduced soil loss

Benefits derived from using adjuvant products are applicable in the treatment tank, during spraying, as well as directly on weeds, pests or target diseases.

In the treatment tank, these substances mainly act on two factors. These directly influence protection of the active ingredient (a.i) from chemical, fungicide, insecticide or herbicide products, such as the pH control of the treatment broth and water hardness.

The pH is intimately linked to the preservation and the phytosanitary degree of effectiveness dealing with the phytosanitary product’s active ingredients. This decreases drastically if we move away from the optimum range (5.5 - 6.5 pH). In this way, the adjuvants produce an acidifying effect, which ensures an optimum pH, guaranteeing maximum phytosanitary expression of the products.

On the other hand, they act and modify the complexation process, which immediately shows cations in hard waters (Ca ++, Mg ++, Fe +++, Si ++++, etc.) produced by hard waters, blocking anions (more of phytosanitary products have negative charge) that interfere in the dissolution of chemical assets during treatment broths. Ultimately, allowing to free assets in order for it to carry out its action on the target pest and, or, disease.

During the spraying process, they give the treatment broth physicochemical characteristics. This calls for a more precise and controlled spraying. The main features are described below:

- **Spreading**, reduces the surface tension of droplets (Figure 2)
- **Penetrating**, facilitates passage of active ingredient from phytosanitary product into plant tissue
- **Retaining**, prevents runoff and losses of a.i into the soil
- **Sticking**, sticks contact products to the leaves
- **Moistening**, captures humidity from the air and extends droplet lifespan
- **Diffusing**, facilitates plant translocation
- **Drift control**, improves the performance and precision of spray applications
- **Anti-leaching**, protects from rainfall

Finally, the adjuvants bear their effect directly on the targeted weed, pest or disease, enhancing phytosanitary action. Next, we highlight the effects which are the most important features:

- Offers retention in irregular / non uniform plant shape
- Improves spreading on foliar surface
- Adds penetration properties on foliar cuticle/thickness
- Works to facilitate spreading, wettability and retention on hydrophobic leaves/plants (Figure 3) on the ground, improving coverage with less water volume
- Triple use adjuvant, combining:
  - spreading
  - retaining
  - penetrating

High performance on hydrophobic leaves and safer for crops than classic oils

- The first multifunctional organically-sourced vegetable product
  - Made from sunflower (oil properties) and sugar beet (adjuvant properties)
  - The dual-action adjuvant, water corrector + adjuvant
  - Helps to solubilize pesticides in mix tank
  - Safeguards compatibility and stability
  - Increase half-life by lowering pH
  - Stick adjuvant containing pine terpene
  - Ultra-concentrated stick adjuvant
  - Low dose rate of 0.05% (2.8-4 times lower dose/ha compared to competitors)

Tradecorp International is developing a wide range of agricultural adjuvants, with the objective of creating a relationship with the farmer while providing effective solutions that help improve product competitiveness. This is all within an agricultural market that is increasingly demanding. This range will be on the market under the name ADJUSTAR.

Strengthening and simultaneously completing Tradecorp International’s agricultural solutions portfolio. Showcasing a clear commitment to continue being the benchmark of the fertilizer market and that of bioinsecticidal specialties.

ADJUSTAR RANGE, will revolutionize the adjuvant market. Some features include:

- Super spreading and leader adjuvant on market for pre-emergence herbicides
  - high capacity of soil penetration
  - ensures horizontal and vertical herbicide distribution
- on the ground, improving coverage with less water volume
- Triple use adjuvant, combining:
  - spreading
  - retaining
  - penetrating

- High performance on hydrophobic leaves and safer for crops than classic oils
  - The first multifunctional organically-sourced vegetable product
  - Made from sunflower (oil properties) and sugar beet (adjuvant properties)
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The Application and Development of Pesticide Precision in Japan

Shoichi Yuki, Ph.D
Head of Planning Development Sector at Yamabiko Corporation

The agricultural working population has been decreasing in Japan. On the other hand, the average age of farmers has been increasing. These factors have caused farmland to be consolidated, though agricultural management hierarchy is becoming polarized. To solve these problems, a national project in the agricultural machinery field, entitled “Smart Agriculture”, has been started. The purpose of “Smart Agriculture” is to increase working efficiency and reduce labor costs by using robotic techniques, as well as information and communication technology.

Yamabiko Corporation is one of the leading companies manufacturing crop protection equipment in Japan. Yamabiko Corporation has been encouraged to create smart agriculture by producing crop protection equipment, such as spraying equipment for UAVs and self-propelled boom sprayers for paddy rice.

The multi-rotors is a new technology for spraying applications, and the practical use in the agricultural field is just starting. Japanese farmers are very interested in using this unique aircraft in their farmland. The number of certified helicopters in the country is 2,788. The number of licensed operators is about 10 thousand. Regarding the share of helicopters, 40 % of paddy rice fields are sprayed by unmanned helicopters in Japan.

Regarding industrial multi-rotors, there are a variety of multi-rotors produced by the Japanese and Chinese manufacturers. The multi-rotors is a new technology for spraying applications, and the practical use in the agricultural field is just starting. Japanese farmers are very interested in using this unique aircraft in their field. The number of the certified multi-rotor in 2018 May is 889, and the number of operators who have license is over 3,600.

In the management schemes for UAV’s agricultural applications, UAV manufacturers are needed to take certification tests conducted by the Japanese agricultural ministry. If they pass the test, manufacturers can release the machines for use in Japanese markets. For operators, including farmers and teachers in the training school, they need licenses to operate UAVs in paddy fields. For practical use, there are some rules for spraying applications. Farmers need to have the notification of spraying plans for the year, which include information, such as when to spray, where to spray, who is spraying, and so on. When finishing the spraying season, every UAV, including spraying equipment, needs to be taken for inspection and maintenance. When any accidents unfortunately happen, farmers need to submit accident report to UAV manufacturers and the government.

Japan has a variety of types of high performance self-propelled boom sprayers. Farmers can control all the boom movements, such as tilt up/down, lift up/down and flapping out/in. Japanese boom sprayers have unique structures in their “telescopic boom”. Farmer can adjust the working width according to field shape by using switch lever operations from 8.9m to 15.9m. Basically, sprayers have boom control systems to maintain the boom horizontally. Self-propelled boom sprayers can turn at a minimum rotation cycle of 2.5m at the end of field.

Self-propelled boom sprayer has kind of flow rate control system. This can realize to keep the flow rate per area constant. Thanks to these high quality functions, sprayer can realize very high working efficiency. If farmer use knapsack type sprayer in the field with 30 area, it takes 60 minutes to work. Regarding self-propelled sprayer, it takes only 8 minutes.

In the current solution for self-propelled boom sprayers in paddy fields, Yamabiko self-propelled boom sprayers use GPS assisted guidance systems and automatic steering systems for the vehicle. In the paddy field, it is difficult for farmers to drive the vehicle to avoid driving on rice rows. Auto steering systems handle steering automatically by using GPS signals. This high performance system will contribute to optimize spray operations and saving labor by farmers. To use very high accuracy GPS signal by RTK system, tracking accuracy will be 2 - 3cm during spray operations. Self-propelled boom sprayers can drive and trace pre-programmed tracks automatically, which greatly improve spraying efficiency and productivity. Farmer can also use LCD touch panel monitors. The area sprayed is displayed on the monitor and is effective in preventing duplication or skipping. Turning points are shown on the monitor and helps to achieve smallest turns.

The benefit of the auto steering system for self-propelled boom sprayers is that the sprayer can drive automatically from point A to point B, which are set in advance, without steering. Sprayers can drive according to rice rows, thus avoid damage to rice. At the end of field, farmers steer the handle wheel, sprayers can drive to the next truck by watching the sprayed area on spray monitors. Auto steering systems for self-propelled boom sprayers can realize easy operation of vehicles during spraying operations with high efficiency, high accuracy and high performance.
Growth opportunities using Vive Crop Protection’s Allosperse technology

Jordan Dinglasan
VP Product Development at Vive Crop Protection

Vive Crop Protection makes proven products cutting edge using the Allosperse® Delivery System. Allosperse is a nanotechnology “shuttle” that enables active ingredients to mix better – with liquid fertilizer, other chemicals, micronutrients and hard water. This allows farmers to use these products in new ways to increase efficiency, crop quality and yield.

AgroPages has recently had a dialogue with Jordan Dinglasan, VP Product Development at Vive Crop Protection, who shared his viewpoints about Allosperse® delivery system and its application situation, as well as their future plan etc.

What do you see for the future of applying nanotechnology-based agrochemicals?

This is an interesting question because there’s some misinformation out there about what nanotechnology can do. Nanotechnology doesn’t change what a chemical does – it just changes how it behaves in its environment. Nanotechnology brings incremental – not revolutionary - changes to ag chem.

For example, Vive developed AZteroid FC 3.3 fungicide that contains azoxystrobin. Our use of nanotechnology doesn’t change the azoxystrobin properties – it still controls diseases and increases plant health like any other azoxyestrobion would. In this case, nanotechnology allows azoxystrobin to mix with other things in the spray tank or irrigation pivot, which wasn’t possible before. Any performance benefits come from azoxystrobin – our technology just allows the product to be applied in different ways and at more beneficial times in a crop’s life.

Tell me more about Allosperse - what is it?

The Allosperse Delivery System is a nanoscale, polymer-based delivery system with extremely high ‘tunability’. We can produce many different types of polymer encapsulation particles with different internal and external chemical properties. The inside can be tuned for optimal association with an active ingredient, while the outside can be tuned for whatever behavior is desired - mixability, targeted mobility, stability, etc.

So is Allosperse technology the future?

We view Allosperse as a critical component to innovation in agriculture. Industry consolidation and increased regulatory barriers mean that fewer new active ingredients are being developed each year. We, as an industry, need to find new techniques to improve existing active ingredients, to help them be used in new ways. Delivery systems that help improve how active ingredients behave can provide new life to older chemistry, as well as improving environmental impact. Allosperse technology can be readily applied across multiple crops and/or active ingredients.

Is Vive doing this alone or in partnership with other companies?

We work with many other agrochemical companies to improve their proven products or new active ingredients using the Allosperse Delivery System. We view ourselves as being the “Intel Inside” in these unique products as they hit the market.

Are any products using Allosperse technology commercially available?

Vive was the first to bring nanotechnology to US crop protection and has two commercially-available products and three more awaiting US EPA approval.

Vive’s AZteroid FC 3.3 fungicide (azoxystrobin) and Bifender FC (bifenthrin) insecticide are worry-free, convenient and easy-to-use products that mix uniformly with liquid fertilizers. They maximize yield and profitability in a broad range of crops including corn, soybean, alfalfa, sugarbeets and potatoes. In fact, AZteroid FC 3.3 has been proven to increase sugar beet yield by an average of 3.1 T/ac and sugar content by up to .6%.

Arya Lifsience utilizes Allosperse technology in two commercially available products. Arysta and Vive received the Agraw Award for Best Industry Collaboration in 2017.

So what’s next?

Vive has a deep pipeline of branded products under development and the ag chem industry is very interested in Allosperse and what it can do - now and in the future. Our next generation of nanotech polymers will improve various active ingredients by improving their ability to reach targets below the soil surface by targeted soil mobility.

The third generation of Allosperse technologies will optimize the adhesion and uptake into foliage to improve retention and residual control of foliar applied products, improve viability of formulated biologicals or improve stability of formulations for moderately soluble active ingredients.

All of these are designed to help growers do more with less and create new ways growers can use and benefit from existing active ingredients.
Innospec Active Chemicals

Innospec Agrochemicals offers a diverse range of surfactants, emulsifiers, rheology modifiers, chelating agents and specialty solvents for the agricultural market. We supply formulation additives for crop protection, home & garden, animal health, fertilizers, micronutrients, and tank mix adjuvants.

Established Innospec brand names such as NANS®, EMPICOL® and EMPLAN® are well known in the industry as time tested and high quality products. Combined with the newly established ENVIOMET® brand, the full product line offers effective components and co-formulants for optimizing formulations and enhancing active ingredient performance and delivery.

Innospec believes in close customer collaboration, commitment to continual innovation and product development contributing to a sustainable environment without compromising on performance.

www.innospecinc.com
agrochemicals@innospecinc.com

Interagro (UK) Ltd

Interagro was formed in 1994 and has since then been at the forefront of the development of surfactant chemistry as in-tank adjuvants. It continues to be the pioneering organisation it set out to be, developing and marketing a wide range of innovative products to optimise the performance of agricultural and horticultural inputs.

Today, Interagro boasts over 100 products in 30 international markets, making it one of the leading lights in the specialist spray adjuvant business throughout the EU, Eastern Europe and North Africa.

Interagro work closely with a number of distributors to be able to offer farmers and growers even more cost-effective performance of crop protection products.

http://www.interagro.co.uk/
info@interagro.co.uk

IntraCrop

Working in partnership with leading universities, research institutes and independent scientists, IntraCrop develops and distributes specialty crop inputs throughout Europe. With significant financial backing, we focus on producing adjuvants, bio stimulants and seed treatments that help agronomists and farmers improve productivity and reduce the unit cost of crop production.

www.intracrop.co.uk
admin@intracrop.co.uk

Battelle UK Ltd.

Battelle is the world’s largest nonprofit independent research and development organization. Battelle’s AgriBusiness provides comprehensive registration services for agrochemicals and biostimuclents, from individual safety studies to turn-key projects and regulatory support. Battelle is distinguished through its technology offering including an independent service for the development of new formulations.

Battelle can help you accelerate your agricultural formulation development schedule, gain access to new markets and maintain your competitive edge. We provide an integrated approach to research, development and regulatory compliance to help you move to market quickly and reliably while controlling costs and risks. We offer customized research studies and full registration programs throughout Europe and NAFTA. Among the services and technologies available are:

Development Services

- Batch preparation
- Factory process transfer

Formulation Technology

Update your product mix with cutting-edge formulation technologies for better performance and stability:
- Bioformulation of proteins, enzymes and bacteria
- Capsule suspensions
- Controlled-release systems
- Emulsions and microemulsions
- Seed dressing
- Ultra-fine sub-micron suspensions
- Water-dispensible granules
- Wetable powders

www.battelle.org
j.groome@battelleuk.com

Victorian Chemical Co. Pty. Ltd.

The Victorian Chemical Company (Vicchem) is a specialist manufacturer and global marketer of agricultural and industrial chemical products that is based in Melbourne, Australia.

We provide our customers with friendly, professional service and reliable, high performance products that have been manufactured according to an accredited quality management system ISO 9001.

Vegetable oils are used widely in our manufacture, with the resulting products being typically non-hazardous to both end user and the environment.

Vicchem has a well-equipped laboratory that is used in formulation development and quality control testing.

Our agricultural products include spray adjuvants, wetting agents, surfactants, insecticides, growth regulators and biostimulant control products. Applications include broadacre cropping, horticulture, cotton and pastoral.

Vicchem has strong business relationships with all key Australian distributors of agricultural products and works with industry partners and customers in North and South America, Europe, Asia, The Middle East and Africa.

www.vicchem.com
products@vicchem.com

Agrovista

Agrovista is a leading supplier of agronomy advice, seed, crop protection products and precision farming services. With the most comprehensive integrated arable trials programme in the UK, we can ensure that the evidence-based advice we provide you is unrivalled in our marketplace.

With depots and regional agronomy centres throughout the UK, we are your local crop care experts, committed to helping you farm more effectively and more profitably.

Agrovista Discovery spray application aids improve the performance of plant protection products. Pesticide efficacy is reduced by water quality, poor application and inadequate coverage, retention and uptake on the target surface. Discovery products overcome these challenges.
Aquatrols

Aquatrols was founded in 1955. Aquatrols is headquartered in Paulsboro, New Jersey. For over fifty years, Aquatrols® has been the leading provider of surfactant and other technologies used to optimize soil-water-plant interactions. Aquatrols® offers turf management products that enhance the effectiveness of turf management programs by minimizing water and other resource use. University and independent researchers as well as growers worldwide have conducted research and demonstration with Aquatrols products. We currently have a significant presence in the American, Canadian, and International markets. Each division plays a unique but collaborative role in advancing our ultimate goal of sustainable water use and global resource conservation. We provide highly-effective solutions that address your unique challenges. Aquatrols® has built a global reputation for innovation, reliability and value.

http://www.aquatrols.com/ info@aquatrols.com

Adjuvants Unlimited

Adjuvants Unlimited, LLC, develops formulation solutions for the adjuvant market. We also bring new and unique adjuvant chemistries to market to complement existing technologies. We offer state-of-the-art production of adjuvants offered in bulk and packaged goods, as well as surfactant blends and pesticide additives.

http://www.adjuvantsunlimited.com/ sales@adjuvantsunlimited.com

Borregaard LignoTech

Borregaard operates one of the world’s most advanced and sustainable biorefineries. As a world leader for Lignosulfonates and modified Humic acids, we take great pride of offering the added protection and the fertilizer industries environmentally friendly alternatives to petroleum and coal based chemicals. Our wide range of dispersants like Borresperse, Ufoxane and Greensperse can greatly help to produce high quality dry and water-based formulations. We offer also natural performance-enhancing ingredients for Plant Nutrient and Fertilizer Formulators like our soil conditioners BorriGRO and our micronutrients Borrochet.

www.lignotechagro.com +47 69 11 80 00 for Europe/Middle-East/Africa +1 715 359 65 44 for America +65 6778 0008 for Asia

Biosorb Inc.

Biosorb Inc. is a bio-based company founded in 1998, providing products for rainfastness and weatherability through patented Microponge™ technology. One of the main problems in crop applications is the run-off or dilution of applied materials due to rainfall, irrigation or UV degradation. Traditionally, surfactants have been used to aid the spread of applications over leaf/foliation/fruits surfaces; however, these surface-active agents have a tendency to facilitate the dissolution of chemicals in water and wash-off treatment areas. New natural-based microponge technology is replacing surfactants in chemical and biological applications due to absorption and adhesion properties, providing better contact time and more efficient delivery. Our products include: Biocare®, TopFilm™, TopFilm-F™, and HydradClear™. Our main focus is providing customers with bio-based adjuvants and inert, which help lower the toxicity and chemical load on the environment. Private formulation development is also available. Our products can be used with biopesticides, as well as, with traditional chemical pesticides.

www.Biosorb-Inc.com BiosorbInc@gmail.com

Clariant International Ltd.

Clariant has long lasting experience in producing adjuvants and inert for the crop protection industry. Our portfolio is one of the broadest in the market covering nonionic, anionic and cationic surfactants, blends, solvents as well as polymeric dispersing agents.

www.clariant.com/cropsolutions

Croda

With our industry-leading technologies and unique formulation expertise, Croda’s unmatched range of adjuvants and adjuvants help agrochemical customers get the best performance out of their active ingredients, enabling farmers to get the best yields for their crops. Our adjuvants and formulation aids under the renowned brands, Aplus™ and Atlox™, are well known in the industry as high performance, reliable products. Our wide range of products cover many areas such as; drift reduction technology, uptake enhancement adjuvants, superior inerter modifiers, high electrolyte solutions and advanced dispersant technology. Our value adding technology helps our customers achieve more efficient, safer, high performing formulations that minimise impact on our environment.

www.agroctl.com gazzari@agroctl.com

Central America Toll-Manufacture & Logistics (CTL), - is a hub for manufacture AG products, focused in competitiveness & service. Covering Central America, Caribbean, Mexico & United States markets, manufacturing in a Foreign Trade Zone. CTL is a company dedicated mostly to manufacture under contract “CUSTOM MANUFACTURE” for crop protection products providing and efficient supply chain that integrates materials, productions and logistics, aiming to continuously improve the level of competitiveness of our customers.

www.agroctl.com gazzari@agroctl.com

AgraSyst

AgraSyst is a specialty Agricultural Spray Adjuvant Company that uses science to design, and manufacturing high performance agricultural spray adjuvants.

AgraSyst designs, engineers and builds premium multifunctional spray adjuvants. Adjuvants that solve problems. Spray adjuvants are a key factor in improving herbicide performance. But not all Spray adjuvants are alike. AgraSyst's adjuvants are engineered to maximize the performance of your herbicides and are designed to be simple and convenient thus saving you time and money.

http://www.agrasyst.com/ scott.parrish@agrasyst.com

Adjuvants Plus Inc.

Adjuvants Plus Inc. was built on the premise that innovation with existing chemistry would open up new avenues in the crop protection industry by creating added value for growers. Product innovation can be measured in a number of ways, one of which is whether these inventions are patentable. As a result, Adjuvants Plus has built a very exciting, specialized product portfolio that has utility in North American and in global markets. Our technology provides growers with new tools to improve crop yields and increase returns in a sustainable manner.

http://www.adjuvantsplus.com/ info@adjuvantsplus.com

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www.agroctl.com gazzari@agroctl.com

Corbion

Corbion is the global market leader in lactic acid, lactic acid derivatives, and a leading company in emulsifiers, functional enzyme blends, minerals, vitamins and algae ingredients.

We develop sustainable ingredient solutions to improve the quality of life for people today and for future generations. For over 100 years, we have been uncompromising in our commitment to safety, quality and performance. Drawing on our deep application and product knowledge, we work side-by-side with customers to make our cutting edge technologies work for them.

At Corbion, we live our brand promise “Keep creating”, through our science, health, nutrition, resource efficiency and sustainability.

Dow Crop Defense

Dow Crop Defense is a global solutions provider of inert and additive agrochemical ingredients for both adjuvants and pesticides with in-depth product performance expertise to meet specific needs of our customers by customized solutions and global supply capabilities.

Dow Crop Defense Solutions
- Focused on the agrochemical market: Preservation, Formulation, Ag Nutrition, Ag Intermediates
- Primary product focus – Surfactants, Amines, Solvents, Chelants
- Our newly introduced POWERBLOX™ Products serve as the building blocks for formulation success
- DOW: wide range of additional products for agricultural markets – Rheology Modifies, Preservatives, Polymethylenes

Eastman Chemical Company

Eastman is a global specialty materials company that produces a broad range of products found in items people use every day. With the purpose of enhancing the quality of life in a material way, Eastman works with customers to deliver innovative products and solutions while maintaining a commitment to safety and sustainability.

Eastman’s diverse AgChem Intermediates portfolio includes neutralizing agents, intermediates as raw materials, insecticides, fertilizers, herbicides, adjuvants, and a variety of solvents and catalysts. With a rich history of providing targeted, innovative, and sustainable solutions, Eastman remains the cream of the crop.

Exosect Limited

Exosect is a lean formulations company. We exploit the characteristics of our unique, proprietary technology platforms and apply our extensive formulations know-how to enable the efficient, targeted delivery of biological and synthetic active ingredients.

Our technology platforms deliver a unique mix of commercial and environmental benefits and are underpinned by an extensive and robust patent portfolio.

We out-license access to our technology platforms, formulations know-how and intellectual property to industrial partners enabling them to grow their business and increase ROI.

Exosect’s Lean Formulation® is based on the use of micro-powders to accurately target biological and synthetic active ingredients.

Using the micro-powder platforms, we accurately place active ingredients on targets, such as seeds, grains, pellets, insects, foliage and building structures.

Our technology and know-how enables us to help our partners with a range of formulation challenges such as reducing the concentration of synthetic active ingredients by 50%, increasing biological loading by 100% and improving the shelf life of biological material.

Our platforms have the potential to deliver in dry and wet format and to deliver multiple active ingredients in a single formulation.

Exosect offers a unique approach to delivering active ingredients in granular formulations.

GarrCo Products Inc.

GarrCo Products is an independent manufacturer and distributor of adjuvants and associated products that enhance pesticide performance and provides a wide range of services.

We’re committed to excellence in research and product efficacy. We focus on customer needs and market trends, which drives our research and product development efforts. This philosophy results in products that are superior, functional, and economical for the end user. Developing and marketing practical, value-driven products that benefit the end-user and not the marketers of adjuvants are a key, basic principle of GarrCo Products. This creates great value, and, easy to use premium performance products.

GarrCo can private label products, develop custom formulations and do research for many different applications.

Foreverest Resource Ltd.

Foreverest Resources Ltd. supplies pine-based chemicals since 1988. Our ranges focus on modified rosin resins, turpentine derivatives, polyterpene resins and flavor-fragrance raw materials. On the agricultural market, we supply the natural extracts adjuvants for fungicides, potentiators, pesticides, PINEVE Emulsion is our owned brand for this powerful application.

https://foreverest.cn/products info@foreverest.cn
GreenA BV

**Squall**

Squall is a product of GreenA.

GreenA is the technology transfer company of the Institute of Physics at the University of Amsterdam. GreenA develops and markets the patented polymer adjuvant and co-formulant Squall to be used with water-based agrochemicals. Squall is typically mixed as a 0.5% solution in the tank mix of spraying installations. Rain fastness improves by 50% and giving a superior deposition of crop protection on the leaves. Adding Squall to in-tank mixtures reduces droplet drift to 5% of the total, compared to 20% seen in standard mixtures of water and pesticides. Squall is widely used already in the Netherlands, Germany, Austria and starting 2018 in Switzerland.

www.squall.pro
p.buis@greena.nl

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**GLOBAL ADJUVANTS COMPANY (GAC)**

GAC was established in 2015 in UK to create a global brand in adjuvants by investing in data to secure registration positions whilst supporting sales with trials and marketing promotions. We aim to demystify the use of adjuvants for distributors and farmers, so they become a tool for environmental benefit and improved agronomy.

Historically adjuvants have been viewed with suspicion by many growers who viewed them as something used by distributors to increase profit margins, rather than a practical agronomy tool that can benefit the crop. Our mission is to show how the correct adjuvant, used in the correct conditions, can be a tool to improve the delivery of crop protection products, providing the farmer with higher efficacy, leading to better yields, and less waste of valuable pesticides. Increasingly adjuvants are also being used for their environmental benefits, such as reducing drift, reducing water use, reducing pesticide resistance, and reducing pesticide environmental effects such as soil leaching.

GAC is also at the forefront of developing new adjuvants suitable for use with biocontrol agents, and for use in IPM and organic (eco) farming. All of these can be said to have a "Positive Environmental Impact".


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**Ingevity**

Ingevity provides specialty chemicals, high-performance carbon materials and engineered polymers that purify, protect and enhance the world around us. As the world's largest producer of Kraft lignosulfonates, Ingevity is committed to quality, consistency and control in the manufacturing of dispersants and surfactant systems. We offer a range of bio-based specialty inerts for plant health and crop protection, and find customers' solutions by combining quality products and unsurpassed technical expertise. Ingevity's adjuvant products are sold under the brand names Altapyne® and Atlantisky™. Headquartered in North Charleston, South Carolina, Ingevity operates from 25 locations around the world and employs approximately 1,750 people. Learn more at www.ingevity.com.

www.ingevity.com
chemicals@ingevity.com

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**iFormulate**

Formulate Ltd provides customised R&D and innovation services to companies working in Formulation Science and Technology. We offer consultancy, problem solving, R&D support, idea generation and development, assistance with commercialisation, and training. Our clients come from the agrochemical and biocides industries as well as other formulating industries (e.g. pharma, biocides, coatings, inks, food, cosmetics, household, specialty chemicals).

http://www.huntsman.com/corporate/athome
athanasia_zavalas@huntsman.com

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**IMCD Group BV**

IMCD is a global leader in the sales, marketing and distribution of specialty chemicals and food ingredients. The experience gathered over the last 20 years has enabled IMCD to acquire extensive knowledge on regulatory and technical requirements in the crop protection, adjuvants and nutrients markets.

IMCD focuses on partnering with prestigious suppliers that offer leading and innovative products into the agrochemical market. The vast portfolio of products available through IMCD’s distribution network provides the industry with a complete range of inerts to achieve optimised formulations such as developing more sustainable solvents; adjuvants to optimise the application target; co-formulants to reduce volatility and sensitivity of new active substances.

In addition, inerts for biotechnology allow IMCD to complete it’s product portfolio to overcome today’s environmental challenges. Through our human resources, supply chain expertise and the creation of the open and lasting partnerships, IMCD provides optimum tailored solutions on formulation, production processes and application for multi-territory distribution management in EMEA, Asia-Pacific and Americas.

Headquartered in Rotterdam, The Netherlands, IMCD achieved a turnover of EUR 2,379 M in 2018 and employs over 2,800 professionals in more than 45 countries. IMCD offers its 37,000 customers a comprehensive and complimentary portfolio of 30,000 products together with expert technical advice and formulary support.

www.imcldgroup.com
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**Lonza**

Lonza has a well-recognised presence in the world's crop protection industry. A custom manufacturer of active ingredients, and intermediates, for many years, the company has established strong relationships with leading plant protection manufacturers and innovators, as well as developing ready-to-use formulations such as the metaldehyde-based AXCEL® slug pellet. As one of the world’s most-trusted suppliers to the pharmaceutical, biotech and specialty ingredients markets, it harnesses science and technology to create products that support safer and healthier living and that enhance the overall quality of life. Its recent launch of VELCIS® provides a new range of formulation ingredients and development services, helping manufacturers to keep pace with new formulation trends, such as biopesticides, added-value formulations of post-patent molecules, and regulatory-driven product reformulations.

www.lonza.com
agroformulation@lonza.com

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**Ionica**

Ionica is a business-to-business (B2B) network that brings together European manufacturers and suppliers of active ingredients and adjuvants with solution-oriented operators and formulators, across all industries and product categories. Our aim is to provide technologies, technical support and advice for safer, cleaner, more effective solutions in rural areas.

http://myionica.com/indexE.html

www.imcldgroup.com
Lamberti

Lamberti SPA through the Business Unit Agrochemistry, develops and produces, within its technological platforms, molecules and solutions instrumental to generate value in the agricultural market, either as tank mix adjuvants or as additives, for new and better performing formulations of crop protection and nutrition products.

Thanks to continuous innovation and close collaboration with its partners, including consultancy for formulation development, the Company has earned the reputation of a solid technological partner. By combining environmental protection and nutrition products, Lamberti designs agrochemical delivery platforms, molecules and solutions instrumental to generate value in the agricultural market, either as tank mix adjuvants, in-can adjuvants and foam control agents available. Used in over 70 countries around the globe, they consistently enhance spreading and coverage while helping reduce manufacturing and delivery costs.

“*Our Silwet and AgroSpréd adjuvants can provide exceptional spray coverage of crop and plant surfaces; excellent penetration for better agrochemical efficacy; and better adhesion and rainfastness to lower pesticide wash-off and waste.

“Our durable, stable SAG anionfoam can produce rapid de-foaming and long-lasting resistance to re-foaming during pesticide manufacturing or tank mixing, while lowering use levels and improving performance.

With ever-growing demand for environmentally responsible agricultural productivity, Momentive will continue to work closely with our customers. Our reliable, sustainable solutions contribute vital assistance to the agriculture industry, today and into the future.

www.lamberti.com
agrochemicals@lamberti.com

LEVACO Chemicals GmbH

LEVACO Chemicals GmbH has its headquarters and production site in the Chempark Leverkusen. Our product portfolio includes specialties such as dispersants, emulsifiers, wetting agents and anti-foaming agents. Our products are used in the segments of agricultural chemicals, fibre manufacture as well as paints and coatings. In addition, we also manufacture specialty chemicals for major chemical companies on a contractual basis. We are a member of the Diersch & Schröder Group based in Bremen.

www.levaco.com
info@levaco.com

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POLAQUIMIA

Our Silwet and AgroSpréd adjuvants can provide exceptional spray coverage of crop and plant surfaces; excellent penetration for better agrochemical efficacy; and better adhesion and rainfastness to lower pesticide wash-off and waste.

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With ever-growing demand for environmentally responsible agricultural productivity, Momentive will continue to work closely with our customers. Our reliable, sustainable solutions contribute vital assistance to the agriculture industry, today and into the future.

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STEPAN COMPANY

Stepan is a major manufacturer of specialty chemicals including surfactants, antimicrobials, fabric softening quaternaries, phthalic anhydride and polyurethane polyols, as well as specialty ingredients for the food and nutraceutical markets. Stepan was founded in 1932 by Alfred C. Stepan Jr. Today, the company has 18 global manufacturing locations, more than 2,100 employees worldwide and over 1,800 product offerings.

Stepan Agricultural Solutions offers a robust pipeline of innovative products and actively seeks to be the strategic supplier of choice for your agricultural chemical needs. Our global research network and geographic footprint is such that we can effectively meet the needs of our customers around the globe.

In addition, our industry-leading, in-house formulation expertise in emulsifiable concentrates, microemulsions, suspension concentrates and dry products provides a value-added service to help solve customers’ most difficult challenges.

http://www.stepan.com/
techserv@stepan.com

SOLVAY

With an increasing demand and a limited potential of cultivated area

The yield increase performance in plant protection and plant growth in a cost effective and safer way is crucial for tomorrow’s agricultural future developments.

All our solutions are expected to provide a wide range of benefits: protection of farmers and of the environment, and enhanced plant quality.

For crop-protection applications, Solvay is dedicated to optimize the use of pesticides while guaranteeing plant vitality and yield per hectare. Our solutions satisfy regulatory requirements and the challenges of sustainable development while simultaneously protecting human health, soil quality and crops.

For fertilizer protection, we provide innovative formulations based on urease and nitrification inhibitors.

www.solvay.com
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SASOL

Sasol is an integrated chemicals and energy group based in South Africa with more than 30,000 employees in 33 countries worldwide.

Our Performance chemicals division is a leading global producer of linear alky benzenes (LAB) fatty alcohols, isoparaffins, surfactants, waxes etc. We offer the formulator or manufacturer one of the most diversified global portfolios of C6+ alcohols, surfactants and specialty chemicals.

Sasol offers the agrochemical customer and manufacturer many choices from our diversified portfolio of products which can be used as components within a broad range of crop protection, fertilizer & dairy applications. Our portfolio of products can be tailored to the agrochemical application targeted. We can use our extensive alcohol portfolio and LAB production to manufacture a fully integrated surfactant portfolio from DDMBA to various anionic and nonionic surfactants.

The Sasol agriculture team leverages our manufacturing operations around the world to offer solutions to our customers. Since Sasol offers many of the same products in different regions of the world we can help our customers overcome many of the challenges of a global business.

http://www.sasol.com/
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Schneider Formulations Consulting

Schneider Formulations Consulting is an enterprise founded and owned by Dr. Rudolf Schneider and specialized in supporting agrochemical companies in development of crop protection formulations. We are based in Basel, Switzerland.

Profile:
Dr. Rudolf Schneider is a renowned expert in formulation of crop protection products. During his career with multi-national companies he has acquired extensive knowledge in formulating a wide range of active ingredients. He has developed a number of successful market products and has re-formulated many products to meet new regulatory...
Vive Crop Protection

Vive makes proven products cutting edge using the Allosperse® Delivery System. Allosperse is a nanotechnology “shuttle” that enables active ingredients to mix better — with liquid fertilizer, other chemicals, micronutrients and hard water. This allows farmers to use these products in new ways to increase efficiency, crop quality and yield.

Allosperse is used in a number of fertilizer-compatible insecticides and fungicides on the market, including partner brands. Vive works with various companies to improve formulations to improve shelf life, mixability and longevity (in the case of biologicals). Vive’s lead products are AZteroid FC 3.3 fungicide and Bifender FC insecticide.

www.vivecrop.com
products@vivecrop.com
Function:
- Increase droplet size (drift reduction) and improve deposition rate (improved efficacy) in aerial application
- Enhance water and nutrient uptake in seed caring & fertilization

Origin: Based on green chemistries
- Guar gum bio-polymer
- A cold-water-soluble polysaccharide derivative

www.jingkun.cn  ivy@jingkun.cn  Tel:0086(0)512-57665261  Mobile:0086-13621554651