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Executive Summary

Chapter 1: Introduction

The scope of this report includes tank-mix adjuvants and built-in adjuvant systems. The framework covers utility adjuvants and additives with functions relating to the period during the spraying operation before target contact; and activator adjuvants, which act after contact with the target to improve efficacy.

Adjuvants are designed to achieve biological, chemical or physical effects to improve the efficiency of crop protection operations and end-results. Tank-mix adjuvants give both the manufacturer of crop protection products, and farmers and growers the flexibility to optimise the cost-efficiency of spraying. Developments in formulation chemistry and in the biological understanding of adjuvancy have led to the development of many sophisticated crop protection products marketed as having ‘built-in adjuvant systems’.

Although the values of adjuvant markets, especially in the context of the scope of this report, are not readily definable, important perspectives are given by the size and detail of the herbicide market within which adjuvants are mainly used.

The future market for adjuvants will be strongly impacted by the drive for product differentiation; regulatory requirements including the need to mitigate against spray drift; continuing use of glyphosate, increasingly supported by selective herbicides to combat weed resistance; growth in Latin American markets and in fungicide and insecticide markets.

The regulatory processes for adjuvants in Europe and the US are described.

Trends in adjuvant research as tracked through scientific literature and conference papers are overviewed.

There are a number of organisations, associations and regular conferences relevant to the adjuvant sector and these are listed and profiled.

Chapter 2: Why use adjuvants?

Spraying operations, from handling concentrates and tank-filling to achieving maximum biological efficacy, include various inefficiencies. Adjuvants and additives provide solutions to some of the problems encountered.

Problems with spraying operations can be conveniently considered as those encountered before or after contact is made with the target. There are also opportunities for formulation additives and bout marking.

During preparations for spraying and transit to the field there may be issues of foaming, water quality and incompatibility between tank-mix partners. Before contact is made with the target spray drift may pose a serious problem.
When spray contacts the target, events with potential sub-optimal outcomes for efficacy unfold.

The first step is deposition of spray droplets on the target. Droplets are retained on the target by wetting and spreading to form discrete spray deposits.

The composition and state of the spray deposit influence the extent to which an active ingredient can exert its effects. This is determined not only by the components of the formulated concentrate of the product applied, but also by the water used to dilute it, including whatever ions and other contaminants are present.

The final step is penetration (also often referred to as uptake or absorption) into the target.

**Chapter 3: Adjuvant classification**

Each of the wide variety of classes of adjuvants and additives are listed, described and aligned with the uses discussed in Chapter 2.

There is limited standardisation and rationale over the use of terminology and taxonomy in the adjuvant sector. Underlying this is the tendency to define categories based on either chemistry e.g. non-ionic surfactants or effects, e.g. stickers.

This is acknowledged by using a framework based on pre- and post-target contact to describe the range of additives, and utility and activator adjuvants.

Pre-target contact: Utility adjuvants improve the operational aspects of delivering active ingredients to the target; sometimes referred to as spray modifiers. Additives are other ingredients with generally physical effects usually used in concentrate formulations or as adjuncts to spraying operations.

Post-target contact: Activator adjuvants improve efficacy, sometimes referred to as enhancing bioperformance.

**Chapter 4: Adjuvant selection**

Some ground rules for selection of adjuvants are discussed, with the focus on making an informed choice of adjuvant to improve biological efficacy.

Important factors in selecting appropriate adjuvants concern certain characteristics of the active ingredient and the adjuvant. There are a number of physico-chemical properties that influence the behaviour of each in the spray solution and their compatibility, on and inside the target.

Within the overall context of application on the farm, the nature of the target, and environmental influences are also important. In addition, there are regulatory drivers.
For more information on the selection of adjuvants, please refer to the chapters on Herbicides and on Fungicides and Insecticides.

**Chapter 5: Herbicide adjuvants**

Activator adjuvants are most often used with herbicides. This chapter is concerned with the basic understanding and established practices of enhancing the activity of major classes of herbicides with adjuvants, and with new developments to be found in the scientific and patent literature.

The attention given to glyphosate has driven a great deal of the progress made in understanding how adjuvants work and how to match them with active ingredients, targets and cropping systems.

The ‘fops, dims and dens’ (ACC-ase inhibitors) and the sulfonylureas have been two other major areas of herbicide chemistry that have benefited from the development and application of adjuvants.

Glyphosate is poorly absorbed through plant cuticles. Good surfactants for glyphosate increase retention and wetting, but do not spread well. Higher HLB cationic surfactants work well, but may be irritants and toxic to aquatic organisms, and a wider range of options are now available. Ammonium sulphate is routinely used in many parts of the world as an adjuvant for glyphosate to increase activity in situations where Ca++ and/or other bad ions are present in spray water.

ACC-ase inhibitor herbicides (‘fops’ and ‘dims’) are lipophilic active ingredients responsive to oil-based adjuvants.

Sulfonylurea herbicides are responsive to several classes of adjuvants including non-ionic surfactants, crop-oil concentrates and ammonium sulphate.

Recent journal and conference publications cover topics including the performance of adjuvants with new products; overcoming antagonism between tank-mixed herbicides, new adjuvants and understanding weed target characteristics important to adjuvant action.

PCT patent publications from 2012-2020 are listed. These cover new activator adjuvants of general use in crop protection and adjuvant technology focusing on herbicides. Reducing the volatility and spray drift of auxin herbicides 2,4-D and dicamba have been major topics. The non-selective herbicides, especially glyphosate, but notably glufosinate too, have been popular targets for improved performance by adjuvants.

**Chapter 6: Fungicide and insecticide adjuvants**

Although herbicides remain most important for activator adjuvants, over the past decade or so there has been growing interest in using adjuvants to enhance the performance of fungicides and insecticides.
The use of adjuvants with fungicides must consider factors including whether the active ingredient has protective, curative or other types of action in plants; permitted residue levels; and adjuvant ingredients must not be phytotoxic.

Commercial examples of adjuvant-enhanced fungicide formulations have generally targeted rainfastness and used finer particle sizes or incorporated spreaders and stickers.

Some older publications on adjuvants for fungicides concentrated on the potential benefits of using organosilicone surfactants to improve the coverage of contact fungicides and studied adjuvants for use with triazole and strobilurin fungicides. Credible new publications are sparse but include continued interest in organosilicones and reports of new adjuvants.

Insecticides have also received much less attention regarding the potential for enhancement of efficacy by adjuvants. Most earlier reports involve organosilicone surfactants. Summaries of a selection of recent papers in the scientific literature are included.

Patent applications submitted since 2012 concerning new classes of surfactants and other adjuvant chemistry, and their application for use with fungicides and insecticides are listed.

Chapter 7: Spray drift control and drones

This chapter covers the topic of spray drift and the use of adjuvants to control it. An emerging topic in this general area is the potential for adjuvants to reduce the risk of drift when spraying crop protection products by drones.

Recent publications show that anti-drift adjuvants can be effective. However, the composition of adjuvants tested is rarely revealed.

Patents are regularly published claiming adjuvants that reduce spray drift.

Japan, China and S. Korea were early adopters in using drones to spray crop protection products.

An important issue around the adoption of drone technology in Europe, N. America and other regions outside Asia is the drafting of regulations controlling flying them per se and their use for crop spraying. The debate on regulations also concerns the authorisation for aerial application of specific crop protection products.

Fine droplets from low water volumes and vortices caused by rotors are particular issues affecting the risk of spray drift when spraying by drone.

Studies reporting on tests with various adjuvants added when spraying by drone are now being published. However, these tend not to have investigated the fundamental reasons for good or bad performance and usually do not disclose details of adjuvant composition.
Chapter 8: Agrochemical companies

Profiles of major crop protection companies that put significant emphasis on adjuvants in their R&D and product portfolios are included.

Agrochemical companies use adjuvants for product line extension and for differentiation of generic active ingredients, as well as product lines in their own right, which are heavily marketed.

Innovative built-in formulations provide a means of competitive advantage and extending product lifecycles. Tank-mix adjuvants provide flexibility in terms of application rate and being able to be used with different products.

Indications of recent research and patenting activities of companies are provided.

Companies profiled are ADAMA, BASF, Bayer CropScience, Corteva, FMC, Nufarm, Syngenta and UPL.

Chapter 9: Speciality chemical companies

Speciality chemical companies are profiled.

The speciality chemical companies are the manufacturers of adjuvant ingredients and operate in various parts of the supply chain. At the most basic level, they supply ingredients to formulators and adjuvant manufacturers. However, some specialty chemical companies also manufacture and sell tank-mix adjuvants under their own brands.

Indications of recent research and patenting activities of companies are provided.

Speciality chemical companies involved in adjuvants for agrochemicals include: Ashland, Borregaard, Clariant, Croda, Dow, Drexel, Evonik, Ingevity, Huntsman, Lamberti, Levaco, Lonza, Momentive, Nouryon, Oleon, Oxiteno, Solvay, Stepan, Victorian Chemicals.

Chapter 10: Specialist adjuvant companies

Specialist adjuvant companies profiled include: Action Pin, Adjuvants Unlimited, Agridyne, Agrofina, Aquatrols, Brandt, Chemorse, De Sangosse, Exacto, Garro Products, Helena, Interagro, Lonza NZ, Loveland Products, Norac Concepts, Precision Laboratories, SACOA, Wilbur Ellis, WinField, Zelam.

Indications of recent research and patenting activities are provided.

Adjuvant research companies include Plant Protection Chemistry New Zealand (PPCNZ) and SurfaPlus (Netherlands).
Figure 1: Market shares of herbicides in 2018 (Phillips McDougall)

1.6.2 Tank-mix adjuvant markets

According to BIS Research, the global agricultural adjuvants market was expected to grow from $2.8 billion in 2016 to $3.6 billion by 2021 at a CAGR of 5.5% (Tanwar, 2019). The basis of such figures is unclear, but other sources also estimate a similar current market value and growth rate. North America is the largest market, with about 40% market share.

Back in 2004, the US tank-mix adjuvant market was estimated to be worth about 35% of the global market of more than $1 billion at the end-user level (Underwood, 2004). At that time in the major market of the US Mid-West, non-ionic surfactants and various types of crop oil concentrates (mineral or vegetable oils, or esterified derivatives) were each estimated to have about 25% market share. Adjuvants based on UAN or ammonium sulphate, and delivery aids (including buffers, anti-foams, compatibility and drift control agents) took around 20% each. Spreader-stickers had just under 10% share.

N. Dakota State University has published data on the range of prices (farmer level) of various types of tank-mix adjuvants. Key selections of these are shown in Table 1 (US units) and Table 2 (metric units). From these data it has been possible to calculate typical costs per acre. Note that these data are some ten years old but have been included in the absence of more recent data.
2.4.2 Wetting and spreading

Wetting and spreading are features of the deposition and retention process. Wetting results in:

- Better contact of spray droplets with the target surface, making them less inclined to roll or bounce off.

- Improved dry down of spray droplets to deposits, giving better coverage, adhesion and possibly better uptake of active ingredient.

Spreading of the initial liquid deposit is a continuation of the wetting process, including wetting-out of difficult to reach places. It affects the local concentration of active ingredient per unit area of contact and, therefore, establishes the diffusion gradient across the cuticle. The greater the difference in concentration on either side of the cuticle, the more easily penetration is achieved. Hydrophilic (‘water loving’), polar active ingredients such as glyphosate may be antagonised by excessive spreading, because this reduces the diffusion gradient for uptake and because more thinly spread deposits will tend to lose water by evaporation more rapidly, potentially limiting the time for uptake. An extreme example of this is when ‘super-spreaders’ organosilicone surfactants are applied with glyphosate and antagonism results (Ramsay et al., 2005) – except in specific cases where the redistribution of active ingredient is beneficial. This is much more likely to be the case with protectant fungicides and insecticides (see Chapter 6).

Stock & Holliday (1993) noted that more lipophilic surfactants (e.g. with fewer ethylene oxide units for those in which the hydrophile is a polyethylene oxide chain) tend to be good spreaders and have a low equilibrium surface tension, and vice versa with more hydrophilic surfactants.

Figure 2: Wetting and spreading of spray droplets/deposits (NB Angle θ is known as the contact angle)
The dynamic surface tension (DST) defines the speed at which surfactant molecules move from being randomly dispersed in the spray droplet to orientate themselves at interfaces, particularly the water/air interface. This determines the surface tension of a spray droplet at impact and, therefore, its retention on the leaf, its wetting properties, and how spray deposits go on to spread over leaves.

The critical micelle concentration (CMC) is the surfactant concentration above which micelles form. Micelles are aggregations of colloidal active ingredient particles suspended in water and surrounded by a ‘shell’ of surfactant molecules. Micelles keep the active ingredient dispersed in water, but in a bioperformance context they make an active ingredient more available for uptake (‘solubolise’).

Viscoelasticity is another property affecting the probability of spray droplets being retained on leaves. If the kinetic energy of droplets can be absorbed, they are less likely to bounce-off.

Some surfactants may form liquid crystals within spray deposits. These can mean that the active ingredient is available for uptake after the deposit has dried down, without rewetting.

Spreaders allow a spray droplet to spread beyond its initial contact diameter, i.e. after wetting (see Section 2.4.2, and Figure 2.). The degree of spreading is influenced by the physico-chemical properties of the adjuvant and the nature of the target surface. Pure water is repelled by waxy, hydrophobic surfaces and so does not spread. The most extreme spreading is achieved by organosilicone surfactants (see Section 3.4.5).

Surfactants are essential adjuvants when the target is hydrophobic. They are not necessary when targets are more hydrophilic (water-loving) and droplets are readily retained on the target. However, most often, e.g. in the case of a spectrum of weed species targets, the characteristics of leaf surfaces will be mixed, so wetters are essential. Surfactants may also effectively act directly or indirectly (because of the greater contact area) as penetrants.

In a tank-mix adjuvant formulation they are often diluted with water, alcohol or glycols. A common nomenclature is to refer to these blends as 90:10 or 80:20, where the first number notes the proportion of surfactant, although ingredients like humectants and others to inhibit gel formation in cold water have often been included too.

Key aspects of surfactants regarding their typology, nomenclature and features relevant to their properties as agrochemical adjuvants are illustrated schematically in Figure 4.
Fluazifop-p-butyl

‘Fops’ are aryloxyphenoxypropionate chemistry molecules including fluazifop-p-butyl (Fusilade), diclofop-methyl (Hoegrass) and haloxyfop-p-methyl (Edge). Premium formulations of Fusilade (fluazifop-p-butyl) e.g. Fusilade Forte (Australia) contain Isolink, a built-in adjuvant system. Isolink is based on a blend of oil and emulsifiers, which enhance penetration into weed leaves. The MSDS notes that these are oleyl alcohol, octan-1-ol and calcium alkyl benzene sulphonate.

‘Dims’ are from cyclohexanedione chemistry and include active ingredients such as sethoxydim (Poast), tralkoxydim (Grasp), and clethodim (Select).

Pinoxaden

Pinoxaden (Syngenta’s Axial) has the same mode of action but is a phenylpyrazoline. In some products the safener cloquintocet-mexyl is included. In the UK, for example, the addition of Syngenta’s proprietary adjuvant Agidor at 0.5% of spray volume is recommended. Agidor is an EC formulation of 47% methylated rapeseed oil. Also stated on the Agidor MSDS are the inclusion of ethoxylated alcohols and the solvent naphtha.

5.5 Sulfonylureas

Sulfonylureas are systemic herbicides with foliar and root action used at typically very low application rates. As, like glyphosate, they deplete plants of essential amino acids (branched chain amino acids: leucine, isoleucine and valine), preventing protein production, they are rather slow acting. Unlike glyphosate, some have
Table 6: PCT patent applications covering new adjuvant chemistry for herbicides 2012-2020

<table>
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<tr>
<th>Patent Number</th>
<th>Applicant</th>
<th>Filing date</th>
<th>Key topic</th>
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<tr>
<td>WO2019169465</td>
<td>Ouro fino quim</td>
<td>1 March 2019</td>
<td>Glyphosate (mixture of K and IPA salts) 400 to 600 g / L (acid equivalent) with a surfactant system formed by an oxidized amine, an aliphatic alcohol, complexing agent and activating adjuvants</td>
</tr>
<tr>
<td>WO2014071475</td>
<td>Oxiteno</td>
<td>13 September 2013</td>
<td>Surfactant composition for glyphosate</td>
</tr>
<tr>
<td>WO2014008562</td>
<td>Oxiteno</td>
<td>15 May 2013</td>
<td>Adjuvant for high concentration glyphosate formulations comprising one or more urea alkoxylate derivatives and other surfactants</td>
</tr>
<tr>
<td>WO2013006860</td>
<td>Stepan</td>
<td>9 July 2012</td>
<td>Compositions comprising an aqueous concentrate of an alkali metal glyphosate, a surfactant blend comprising an etheramine component, and an optional water- miscible solvent</td>
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<td>WO2012152527</td>
<td>Syngenta</td>
<td>13 April 2012</td>
<td>EC formulation comprising pinoxaden and fluroxypyr and phosphate or phosphonate adjuvant</td>
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<tr>
<td>WO2018078478</td>
<td>UPL</td>
<td>12 October 2017</td>
<td>Glufosinate formulations including an organosilicone adjuvant, and a non-ionic surfactant</td>
</tr>
<tr>
<td>WO2016206904</td>
<td>UPL (Arysta)</td>
<td>25 May 2016</td>
<td>A synergistically effective amount of (a) diuron and (b) oxyfluorfen and an agriculturally acceptable adjuvant and/or carrier</td>
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</tbody>
</table>

Source: European Patent Office

5.7.2 Patents claiming general activator adjuvants

The patents covered in this section do not necessarily specify herbicides but focus on the adjuvants per se and their general use in crop protection.

BASF has been most prolific amongst the major crop protection companies in patenting activator adjuvants, followed by Syngenta (Table 7). A recent BASF patent claims a new tank-mix adjuvant based on a mixture of the anionic surfactants classes alkylbenzenesulfonates or sulfosuccinates, and a non-ionic surfactant. A recent Syngenta patent claims built-in adjuvant formulations comprising hydroxy-capped and non-hydroxy-capped aliphatic alcohol ethoxylates.

Clariant, Croda, Solvay and Stepan have been actively patenting over this period, but there has been less activity most recently.

Momentive continues to patent organosilicone chemistry and has recently been interested in mixtures with the phospholipid lecithin.
Table 8: Recent PCT patent applications covering new adjuvant chemistry for fungicides and insecticides

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<th>Applicant</th>
<th>Filing date</th>
<th>Key topic</th>
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<td>WO2013113577</td>
<td>BASF</td>
<td>21 January 2013</td>
<td>Adjuvant containing polyorganosiloxane and organic solvent for preparing a larvicidal tank mix</td>
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<tr>
<td>WO2016161037</td>
<td>Corteva (Dow Agrosciences)</td>
<td>30 March 2016</td>
<td>Increased soil residual activity of sulfoxaflor and other insecticides formulated with nonionic surfactants and EO:PO block copolymers</td>
</tr>
<tr>
<td>WO2016161038</td>
<td>Corteva (Dow Agrosciences)</td>
<td>30 March 2016</td>
<td>Increased soil residual activity of sulfoxaflor and other insecticides formulated with anionic surfactants</td>
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<tr>
<td>WO2018116027</td>
<td>Decco worldwide post-harvest holdings</td>
<td>18 November 2017</td>
<td>Use of cinnamaldehyde with fungicides for the treatment and/or prevention of Black Sigatoka fungal disease in banana crops</td>
</tr>
<tr>
<td>WO2017094676</td>
<td>Kumiai, Nippon Soda</td>
<td>28 November 2016</td>
<td>Pyribencarb formulation including an adjuvant selected from polyoxyalkylene siloxanes, polyoxyethylene/polyoxypropylene block copolymers, and polyoxyalkylene alkyl ethers; a nonionic-anionic surfactant which is a polyoxyalkylene aryl ether sulfate and/or a polyoxyalkylene aryl ether phosphate</td>
</tr>
<tr>
<td>WO2019149670</td>
<td>Nouryon (Akzo Nobel)</td>
<td>29 January 2019</td>
<td>Formulations comprising an alkyliminodipropionate surfactant and an insecticide or fungicide</td>
</tr>
<tr>
<td>WO2017170807</td>
<td>Sakamoto Yakuhin Kogyo</td>
<td>30 March 2017</td>
<td><em>Artemisia capillaris</em> extract having capillin as an active ingredient, a fatty acid glyceride and a surfactant having an HLB of 8-20, and a polyphenol exhibiting a pectin-degrading enzyme activity inhibitory action to protect citrus fruit in storage</td>
</tr>
</tbody>
</table>

Source: European Patent Office

6.8 References and resources


In the UK, the adjuvants of the former company Headland Agrochemicals are now included under the FMC banner. The company was formerly owned by Cheminova, which was acquired by FMC in 2015 for $1.8 billion. Headland had a manufacturing plant and was involved in formulation development. A range of adjuvants are supplied for agricultural and horticultural crops (Table 13).

<table>
<thead>
<tr>
<th>Product</th>
<th>Type</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamond, Fortune</td>
<td>Wetter/penetrant</td>
<td>Mixed fatty acid esters of seed oil and n-butanol</td>
</tr>
<tr>
<td>Intake</td>
<td>Wetter</td>
<td>Propionic acid</td>
</tr>
<tr>
<td>Reus</td>
<td>Wetter/penetrant</td>
<td>Trisiloxane co-polymers</td>
</tr>
<tr>
<td>ZigZag</td>
<td>Wetter/penetrant</td>
<td>Styrene/butadiene co-polymer and polyether-modified trisiloxane</td>
</tr>
<tr>
<td>Guard 2000</td>
<td>Sticker/Extender</td>
<td>Styrene/butadiene co-polymer</td>
</tr>
<tr>
<td>Glow</td>
<td>Water conditioner</td>
<td>Acidifiers, chelating agents, surfactants, stickers</td>
</tr>
<tr>
<td>Holdtite</td>
<td>Pod-sealant</td>
<td>Carboxymethylcellulose sodium salt</td>
</tr>
</tbody>
</table>

Source: FMC website

8.5 Nufarm

Nufarm is an Australian crop protection company, based in Melbourne ranked 9th in the world, with operations in Australasia, North and South America, and Europe. Sumitomo Chemical Company of Japan has a 23% shareholding. Sales revenue in 2016 was $2.8 billion. The company employs 3,400 people.

Nufarm’s range of tank-mix adjuvants include:

- **Activator** (fatty acid/surfactant blend): Foam control, humectancy, improved absorption.
- **Banjo** (methyl esters of canola oil): improves uptake, reduces spray drift.
- **Bond** (sticker): Improves deposition and retention of contact fungicides and insecticides.
- **BS1000** (alcohol alkoxylate): General purpose wetter/speader.
- **Collide 700** (350 g/L soyal phospholipids + 350 g/L propionic acid): improved penetration, acidifying, reduces alkaline hydrolysis of dimethoate.
- **Liaise** (aqueous solution of ammonium sulphate): Reduces antagonistic effects of hard water on glyphosate and bicarbonate ions on ‘dim’ herbicides.
- **Pulse** (organosilicone surfactant): Super-spreading and stomatal flooding to improve wetting of woody weeds and penetration of cereal fungicides into the crop canopy.
- **SuperCharge Elite** (paraffin oil): enhances wetting, spreading and uptake of systemic herbicides tralkoxydim and butroxydim.
- **Wetter TX** (octyl phenol ethoxylate): improves glyphosate performance on hard-to-wet grasses.
Lonza is organised into two market-focused segments: Pharma&Biotech and Nutrition, and Specialty Ingredients. The latter includes agriculture. Lonza offers products for crop protection, including adjuvants and additives through Lonza New Zealand, formerly Zelam Pte Ltd, based in New Plymouth, New Zealand, which it acquired in 2015.

9.15 Momentive

Momentive is based in Ohio, USA. Momentive Performance Materials was formed in December 2006 following the sale of GE Advanced Materials to the private equity firm, Apollo Management. The company manufactures the following product lines with applications in agriculture:

Silwet: includes the original organosilicone ‘super-spreader’ Silwet L-77. More recent additions to the range have been pH stable silicones, including Silwet HS-312 spreader claimed to reduce application rates and enhance efficacy of water-based formulations. Silwet Eco (siloxane polyalkylene oxide copolymer) is approved by the Organic Materials Review Institute (OMRI) for use in organic farming.

AgroSpred: tank-mix adjuvant blends including organosilicones.

SAG: anti-foams.

At the ISAA conference in 2016, Momentive presented an organosilicone spreader-penetrant for use with petroleum-based crop oils and an organosilicone super-sticker.

At the ISSA triennial conference in 2013, Momentive reported a new organosilicone surfactant for use as the emulsifier and spreader-penetrant component in methylated seed oil-based adjuvants.

At recent ASTM conferences, Momentive has made presentations on the following subjects:

ASTM 2018 ... Impact of trisiloxane alkoxylate molecular weight on stomatal infiltration

ASTM 2017 ... Acute toxicity assessment of various organosilicone surfactants to honeybees

ASTM 2016... New organosilicone and lecithin-based adjuvant: effect of lecithin HLB on penetration, adhesion and drift reduction

Recent PCT patents in the area of adjuvants for agrochemicals are presented in Table 20.
WO2020006522, filed on 28 June 2019, claims a drift reduction adjuvant composition contain water, a rheology modifier (e.g., guar gum or polyacrylamide), an emulsifier such as a polyoxyethylene sorbitan emulsifier, and an oil. The percentage of small, drift-prone droplets are reduced.

WO2018126017, filed on 28 December 2017, claims a drift reduction adjuvant composition containing a Newtonian responding polymer such as guar gum, an emulsifier such as a polyoxyethylene sorbitan emulsifier, and an oil.

WinField United presented an NPE-free non-ionic surfactant-based adjuvant called Permeate™ at the Weed Science Society of America conference in 2019 (Edwards et al., 2019). As well as being able to be used when any NIS is recommended to be tank-mixed, Permeate has patented UV protection properties.

AccuDrop™ (AG13064) is a non-oil, surfactant-based adjuvant drift and deposition from Winfield United designed to reduce spray drift and increase droplet deposition (Hayden et al., 2018). It is formulated without nonylphenol ethoxylates. In a wind tunnel AccuDrop added to glyphosate and sprayed through different nozzles reduced the percent of spray particle droplet fines from 16% to 4 - 6% compared to glyphosate alone. Field drift studies also showed significant drift reductions; 3.02 m with the addition of AccuDrop compared to 6.83 m with no drift control added.

StrikeLock® is a novel methylated seed oil adjuvant from Winfield United that optimizes the performance of hydrophobic herbicides with the additional benefit of drift control and droplet deposition (Dahl, et al., 2017).

10.22 Adjuvant research companies

10.22.1 Plant Protection Chemistry New Zealand

Plant Protection Chemistry New Zealand (PPCNZ) is based in Rotorua, New Zealand. PPCNZ conducts laboratory, controlled environment and field research relevant to agriculture, horticulture and forestry. The company originated in 1984 as one of New Zealand’s Forest Research Institute’s (FRI) operational research groups. PPCNZ became an independent research organisation in 2005.

PPCNZ’s work focuses on ‘spray formulation efficacy’ aiming to optimize spray deposition, droplet retention and the uptake and translocation of active ingredients. The first commercial organosilicone surfactant for crop protection products was discovered and tested by PPCNZ in 1980. This was introduced as Pulse (Silwet L-77) in 1985 by Monsanto New Zealand for use with Roundup (glyphosate) for the control of gorse. PPCNZ has particular expertise in organosilicones.

Other areas of success have involved the use of adjuvants in the application of fungicides and insecticides, and the development of models to improve the understanding of processes modified by adjuvants.

At the ISAA triennial conference in 2016, Alison Forster, a director of PPCNZ discussed the influence of leaf surface characteristics and adjuvant properties on droplet spread. Robyn Gaskin, another director, discussed the benefits of an adjuvant as a dormant orchard spray.

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