making every drop count

Codacide Oil

Benefits and Efficacy

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SOIL ASSOCIATION CERTIFIED PRODUCT

Codacide Oil: Benefits and Efficacy

Contents:

I. Codacide Oil's Delivery System:

Codacide Oil is a 95% natural vegetable oil (food grade Canola Oil) adjuvant formulated with a series of plant based emulsifiers (5%). When Codacide is pre-mixed with a plant protection product, the emulsifiers latch on to the product, and when this is added to water in the spray tank, a "controlled emulsion" is formed and it is this that is the key to Codacide's unique efficiency as a carrier of the plant protection product (PPP).

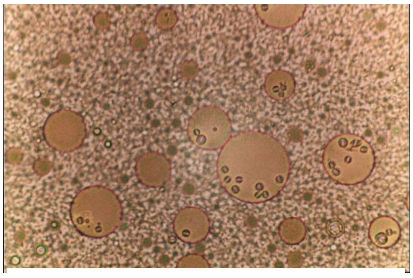


Fig. 1: Metharizium spores with Codacide

Many attributes of water make it inefficient as the primary carrier of PPPs when spraying. Water has a high surface tension and is prone to shattering, resulting in large droplets that are prone to bounce and run-off, or small droplets that drift. Target plants, insects and fungi have evolved over millennia to repel water through waxy epicuticular surfaces, reducing adhesion and retention of PPP deposits. Impurities in water, PH, and salinity can lead to PPP volatization, alkaline hydrolysis, denaturing and neutralization of PPP actives. On target, water does not protect PPP deposits from further neutralization through evaporation, UV breakdown and photodecomposition.

Codacide Oil does not try to change these adverse spraying attributes of water, but rather removes them from having such an an adverse affect on the efficacy of the spraying operation. Codacide replaces water as the primary carrier of the PPP. The pre-mixed controlled emulsion of Codacide and PPP is then only added to water to provide volume. In affect, the adverse spraying attributes of water is removed from the spraying equation. Codacide Oil is an improved delivery system that has more in common with the development of new and improved spray nozzles or mechanical sprayers.

Whilst many adjuvants, surfactants and additives try to modify or change these particular adverse physicochemical attributes of water, Codacide simply replaces it as the primary carrier of the PPP. Codacide Oil does not change the chemical or biological mode of action of the PPP in any way. As a totally plant based vegetable oil product, and unlike mineral oils or Modified Seed Oils (MSOs), Codacide's action is as a carrier and has no biological or chemical mode of action. Rather than trying to change water, Codacide replaces it and in doing so is able to address many of its negative spraying attributes such as:

- Reduce volatization, evaporation, UV breakdown and photodecomposition (refer section III)
- Reduce drift (refer section IV)
- Improve adhesion and retention (refer Section VI)
- Enhance spreading and coverage (refer Section VII)
- Confer rainfastness (refer section V)
- Improve uptake and extend efficacy of herbicide, insecticide, fungicide and biological PPPs (refer Section VIII)

These attributes of Codacide as the primary PPP carrier achieve two fundamental improvements to the spraying operation.

1.) Presents PPP deposits to the target in an optimal manner to ensure effective utilization. Codacide's key attribute is not to increase deposits, but rather to increase their effective utilization through optimal presentation. Codacide assists minimalize the amount of PPP deposit that remain unutilized on targets and also decreases the denaturing of their active ingredients.

2.) Improves the consistency of spraying operations. Farmers encounter very few perfect spraying days and are often forced to spray in less than ideal conditions. Codacide helps deal with these less than ideal conditions – whether it be the quality of water used, too hot, too dry, too wet or too windy. Codacide thereby improves the consistency of spraying – assisting farmers to achieve more ideal spraying application, more of the time. Codacide assists improve consistency of results, thereby reducing the need for re-application and helping limit incidence of resistance.

The extension in efficacy realized by Codacide when used as the primary carrier for herbicides, insecticides, fungicides and biologicals is due to this improved presentation, utilization and greater performance consistency achieved in spraying operations, due to reducing the negative impact of non ideal spraying conditions that farmers are often forced to endure.

II. Codacide Oil is Safe for the Crop, the Consumer and the Environment:

Codacide Oil is inert, food grade, has organic status, is certified by the UK Soil Association (Soil Assocation, 2011) and is a registered approved input of the Guild of Conservation Grade Producers in the UK (GCGD, 2010) and is classified as a white safe product by MPS for all European markets (MPS 2011). Codacide Oil has an excellent toxicology and eco-toxicology profile (refer Codacide eco-tox dossier) and due to its completely safe Risk Profile is REACH exempt and fully compliant for all EU countries. Codacide Oil has been registered in 20 countries (10 European), and used on millions of hectares worldwide on most crops at most growth stages (refer Section VIII.). Codacide in the UK for example, is the only organic registered adjuvant approved for all uses including aquatic ecosystems.

Table 1: Summary of Codacide Oil Country Registrations

Australia	Italy	Portugal
Cyprus	Kenya	Romania
Ethiopia	Mauritius	
Germany	Netherlands	Spain
Greece	New Zealand	Ukraine
Hungary	Oman	United Arab Emirates
Ireland	Palestine	United Kingdom

De Courcy Williams *et al* (2000) attested to the inert nature of Codacide Oil when comparing the potential of 14 adjuvants in promoting the virulence of the entomopathogenic fungus *Verticillium lecanii* in the control of the peach potato aphid *Myzus persicae*. Control mortalities of individual adjuvants without *V. Lecanii* were conducted, and whilst all adjuvants tested (with the exception of SAS 90) showed low aphid mortality controls (up to 10% by day 3 and 10-30% by day 7), only Codacide Oil (2.5 l/ha) showed zero mortality by day 7. The UK's DEFRA (2006 a.) similarly attested to Codacide's inert nature, with Codacide Oil applied alone (2.5 l/ha) having no significant affect in itself on mortality of *Myzus persicae, Nasonovia ribisnigri and Brevicoryne brassicae* aphids (mean 26.7 verses 23.3 in untreated control) in lettuce and Brassica crops (DEFRA, 2006 a.).

Codacide in itself has no adverse affects to non target organizisms. At the Horticulture and Food Research Institute of New Zealand, Goodwin and McBrydie (2000) determined the effect of 11 surfactants and adjuvants on Honey bee survival using laboratory bioassays and found that Codacide Oil had no significant adverse affect on their survival in contrast to surfactants Citowett, Pulse, Boost and Ethokem, which were toxic to Honey bees when applied topically to anoxiated bees.

Koppert (1995) assessed the effect of Codacide alone and when added to Torque (50% *w/w* fenbutatin oxide) on the natural predators *Macrolophus caliginosus* and *Phytoseiulus persimilis* and found that there was no significant difference between mortality after spraying, with or without Codacide.

At the Horticulture Pathology Department, Plant Research Centre, Australia, Wicks (1997) determined if a sensory difference in taint or odour existed between wine produced from vines and grapes treated with Codacide and wines made from fruit not treated with Codacide. Triangle tests were conducted on Chardonnay and Cabernet Sauvignon and no significant difference was found between treated wine and the control.

In addition to the environmental benefits derived from reduced drift and target bounce afforded by the use of Codacide Oil (refer sections IV, VI, VII), the University of Florida (Singh, 1992) found that the use of Codacide Oil also significantly reduces the amount of PPP leaching in soils and consequently can play an important role in reducing pesticide groundwater contamination. Using PBC columns and as determined by ryegrass bioassay, herbicide leaching was assessed for Bromacil, Simazine, Norflurazon, Diuron, Atrazine and Metolachlor when applied alone and when applied in combination with Codacide Oil.

Codacide Oil treatments reduced leaching of all herbicides with the effect varying from 8.6% to 37.5%. Most improvement was found in the case of Simazine where Simazine without Codacide leached to the depth of 11.2 inches while with Codacide moved to only 7.0 inches indicating an improvement of 37.5%. The other significant improvements were observed in the case of bromacil (27.1%), atrazine (22.2%), and Metolachlor (15.1%) (Singh, 1992).

i.) Codacide is Non Phytotoxic:

Codacide does not alter, change or modify the targets epiculticular wax layer in any way to improve penetration or uptake of PPP deposits. Rather Codacide works in harmony with plant, insect and fungal surfaces, to more effectively present deposits for their particular mode of actions to be effectively implemented.

As depicted in Figure 2, Codacide when mixed with PPP forms a thin amorphous film that masks the formations of wax platelets. PPP deposits are presented with a high target surface area contact ratio. After washing with an acetone solvent system, Figure 3 shows how wax platelets are left undamaged. Codacide does not alter target surfaces, but by being of a similar chemical composition (both are triglycerides) adheres to, spreads, and presents PPP deposits effectively. It is this natural affinity with the targets surface that enables the improved uptake of PPPs.

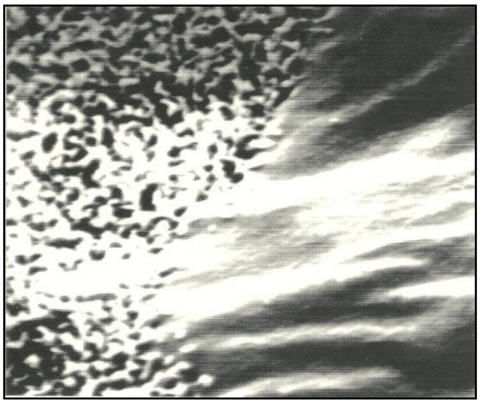


Fig. 2: Codacide + Glyphosate as a thin amorphous film masking formations of wax platelets of wheat leaf (Mag.X5000)

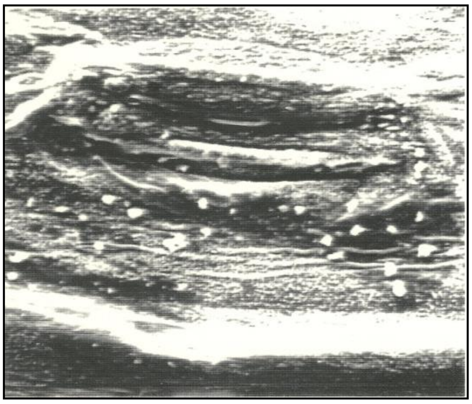


Fig. 3: Following wash with acetone solvent system showing undamaged wax platelets (Mag. X850)

In contrast to Codacide Oil which is the only 100% natural plant based adjuvant with Organic status, other adjuvants are synthetic and have undergone extensive chemical modification to obtain some level of improved penetration and uptake of PPP. This process often results in adjuvants that are as toxic, or indeed more toxic than the PPPs they are used with. Synthetically altered Mineral oils, Organosilicons and Methylated Vegetable Oils (MSOs) have to invasively modify epicuticular surfaces, for increased penetration, that often results in tissue damage and irreversible disruption to the plants normal growing systems. This can, for example, involve leaf wax solubilisation, cuticular penetration and cell membrane disruption (Manthey and Nalewaja, 1990) and subsequently confers a greater risk of phytotoxicity. Where there is such localized damage to plant tissues, both uptake and translocation may be adversely affected (Zabkiewicz, 2002).

Petroleum derived oil adjuvants, Organosilicons and Modified Seed Oils have a lower viscosity (higher distillation temperature) than Codacide Oil and therefore longer perseverance and potential for adverse physical affects and increased phytotoxicity. It is not the physical presence of these oils, but that they contain a range of unsaturated oil molecules (i.e polycyclic aromatics, carboxylic acid, hydroperoxides, phenolic compounds and mercaptans), that can disrupt important foliar membranes, especially when photodegradation (UV breakdown) occurs and results in a readily available pool of these phytotoxic compounds that are known to disrupt cell membranes (Hodgkinson *et al.*, 2002).

Martin *et al* (2005) undertook comprehensive field and growth-chamber phytotoxicity experiments with Codacide Oil on grape vines (cultivar Mencia), at different rates (from 0.25% to 2% v/v). This statistically showed that Codacide Oil had no phytotoxic effects and had no effect in regard to shoot length, number of leaves, number of internodes, and leaf area. Net photosynthesis, stomatic conductance and transpiration rate were analyzed using Infrared gas analyzer (ADC-LCA-3) equipped with a Parkinson PLC-2 leaf chamber and statistical analysis of data was by one-way ANOVA, followed by LSD tests. The results showed that in comparison to water control, Codacide Oil had no significant affect on the transpiration rate, stomatic conductivity and CO2 exchange of grape vines at 4 doses (0.25, 0.5, 1, 2%) and confirms that Codacide Oil does not invasively damage important foliar membranes when presenting PPP deposits for effective uptake (Martin *et al*, 2005).

Codacide has been subjected to extensive selectivity and phytotoxicity studies and trails with a comprehensive range of Plant Protection Products. As summarized in Section VIII, over 100 trials and studies have been conducted on Codacide alone and in combination with comprehensive range herbicide, insecticide, fungicides and biologicals on a diverse range of crops throughout the world in different climatic conditions with no adverse phytotoxicity. Even at double rates (5 l/ha), for instance, Codacide in addition to Quizalofop ethyl D (Targa D+) on sugar beet did not cause any phytotoxicity or any reduction in root numbers, yield, sugar content or sugar yield (Biotek, 2004 a.). Further, the Romanian Research Institute for Plant Protection (1997) analyzed phytotoxicty of Codacide alone at double the recommended maximum rate (5 l/ha) on French beans, sunflower and potatoes with no phytotoxicity recorded.

ii.) Codacide and Residues:

Codacide Oil, as a natural product is readily biodegradeable into carbon dioxide and water. Codacide Oil's main benefit is not increasing the amount of PPP deposits reaching target, but rather improving the effective utilization of deposits once there. Codacide assists minimalize the amount of PPP deposit that remain unutilized on targets and also decreases the neutralization and/or denaturing of their active ingredients.

In spray tanks, pesticides can be denatured prior to reaching intended targets, through alkaline hydrolysis, salt, ph imbalance and the presence of metabolites and impurities in water used for spraying. On reaching the target, further pesticide degradation can be caused through volatization, UV breakdown and photodecomposition. Codacide assists to reduce volatization (MAFF, 1999), tank water degradation (Bateman *et al*, 2005) and limits UV photodecomposition once on target (Alves, *et al*, 2000) (refer Section III).

Water as the spray carrier does not spread well on water repellent cuticle wax. Once the water evaporates, it can leave a pile of dried chemical residue which is not easily available for uptake by the plant, insect or fungus. As evidenced in Section III, VI and VII, Codacide increases the viscosity of the PPP and water and significantly reduces the evaporation of spray formulations on target surfaces and the occurrence of neutralization and surface residue piling of dried PPP deposits.

Fig 4. PPP + Water on Kale leaf surface

As depicted in Fig. 4, PPP plus water deposits can accumulate in leaf crevices resulting in pesticide layering. Mounds of residue are left when layered pesticide is evaporated and dried. Larger droplets (>200 um) are prone to run and accumulate in crevices. The presence of large droplets, due to high Dynamic Surface Tension (DST) and high droplet contact angles presents a low pesticide to target surface area contact ratio with increased pesticide layers unavailable for plant uptake and with a higher chance of evaporative drying leaving residual / enduring piles of residues (Hollaway *et al*., 2000).

Good target coverage depends on both the number and size of spray droplets retained and the amount of spreading that occurs before droplet evaporation is complete. As described in Section VII Codacide reduces the accumulation and layering of PPP deposits in residual piles, through improved adhesion and spreading. Further, and as discussed in Section II i, Codacide does not change or modify the leaf targets epicuticular surface for increased penetration (in contrast to mineral oil or MSOs), but rather works in harmony to present PPP deposits once there for more effective uptake. In this way, Codacide assists PPP actives to undergo unfettered - full and improved metabolism with reduced unutilized, neutralized and denatured deposits remaining on target surface.

Codacide Oil's ability to improve spraying performance to optimize the efficacy of PPPs, also enables users to reduce rates of PPP accordingly when using Codacide to achieve similar control as achieved by full rate PPP application alone. Accordingly, Codacide provides the mechanism for users to reduce residue levels.

Codacide Oil's ability to provide an enabling environment for PPP actives to undergo unfettered metabolism was shown through replicated residue analysis studies undertaken by the UK's Huntingdon Research Centre. Samples were analysed by solvent extraction and extracts purified by liquid partition and quantitation was undertaken by gas-liquid chromatography.

In the determination of concentrations of Pirimicarb (Insecticide) in Wheat and Sugar Beet tops, no significant difference in Pirimicarb applied alone and in Pirimicarb applied with Codacide Oil was found in the residue levels. Indeed for the four samples taken of Wheat ears and grain 12 hrs after treatment, in the majority of cases Pirimicarb and Codacide Oil treatments were found to contain slightly less residue levels of 2.33 – 3.03 ppm verses 3.07 – 4.29 ppm. At time of harvest, four replicated samples showed very low pirimicarb residues for Codacide and Pirimicarb and Pirimicarb alone treatments at under 0.05 ppm. No significant differences in concentrations of Pirimicarb residues found in Sugar Beet tops at 12 hrs after treatment and at time of harvest was also found for Pirimicarb and Codacide Oil and Pirimicarb alone treatments (HRC, 1985 a.).

In the determination of concentrations of Triadimefon (Fungicide) in Wheat and Sugar Beet tops, no significant difference was observed in four replicates of Wheat ears and grains at 12 hrs after treatment, between Tiadimefon and Codacide Oil and Triadimefon applied alone. At the time of harvest, residue levels were so low, as to be beyond the scope of detection at under 0.05 ppm for both Triadimefon and Codacide Oil and Triadimefon applied alone treatments. Similar residue analysis results were recorded for four replicate samples at 12 hrs after treatment and at time of harvest for concentrations of Triadimefon found in Sugar Beet tops (HRC, 1985 b.).

In the determination of concentrations of Ioxynil (Herbicide) in Wheat ears and grains, no significant difference was observed in four replicates of Wheat ears and grains at 12 hrs after treatment between Ioxynil and Codacide Oil and Ioxynil applied alone. At the time of harvest, residue levels were so low as to be beyond the scope of detection at under 0.05 ppm for both Ioxynil and Codacide Oil and Ioxynil applied alone treatments (HRC, 1985 c.).

SAC Scientific (1988) undertook an analysis of the herbicide Glyphosate (Roundup) on Wheat straw and grain samples employing the analytical procedure given in the UK's Standing Committee of Analysts Booklet for the determination of glyphosate in water. Eight samples (4 grain and 4 straw) were analysed with Roundup at 2 l/ha with Codacide Oil (2 l/ha) and Roundup (2l/ha) applied alone providing statistically similar residue levels at <1 mg/kg for the grain samples and 8 and 10 mg/kg respectively for the straw samples (SAC, 1988).

Using Gas liquid chromatography coupled with electron capture detection, Cherwell Laboratories (1988), undertook replicated studies of 12 samples that were analyzed for residue levels to determine the concentration of Cypermethrin (Insecticide) residues in samples of whole apples (Cultivar Cox's Orange Pippin) received from three treatment sites. Cypermethrin (100ml/ha) and Codacide Oil (100ml l/ha) treatments, were found to have similar residue levels as to the Cypermethrin applied alone treatments with residue levels for the Cypermethrin and Codacide treatments being low at between 0.02 and 0.04 ug/g (Cherwell, 1988 a.).

For strawberries, the fungicide Iprodione (Rovral) was applied in three replicated treatments of Rovral alone (3 l/ha and 1.5 l/ha), and Rovral (1.5 l/ha) and Codacide Oil (1.5 l/ha), with last spray 48 hrs prior to harvest. Harvested samples of strawberries were immediately analysed for residue levels of Iprodione, using Gas liquid chromatography coupled with electron capture detection. Residue levels found in Strawberries treated with Rovral (1.5 l/ha) alone were very similar (0.14-0.25 ug/g) to residue levels found in strawberry samples treated with Rovral (1.5 l/ha) and Codacide Oil (1.5 l/ha) (0.16-0.26 ug/g). There was very little difference between the residues obtained from the three treatments but the mean value of the Rovral (3 l/ha) applied alone treatment was slightly greater than the other two treatments (Cherwell, 1988 b.).

In determining the concentration of the insecticide Cypermethrin (Ambush) residues in samples of lettuce plants after harvesting, Cherwell Laboratories (1988) assessed 48 hrs after last spray, four treatments of three replicates each, using Gas liquid chromatography coupled with electron capture detection. Residue analysis of lettuce samples treated with Ambush (140 ml/ha) alone showed values between 0.02 – 0.11 ug/g compared to lower values found in lettuce samples treated with Ambush (140 ml/ha) with Codacide Oil (140 ml/ha) that showed values of between 0.02 – 0.09 ug/g.(Cherwell, 1988 c.)

Codacide Oil's ability to reduce drift through the reduction in small driftable droplets (< 100 ug) reduces PPP pollution of the environment, rather than increase significantly the amount of PPP reaching target. Only when there is perimeter headland spraying in large commercial applications, does drift result in significantly reduced target deposition. The creation of an optimum sized droplet spectrum results in less large runable droplets that are prone to pesticide layering. Improved adhesion, spreading, and the formation of a thin amorphous film of PPP plus Codacide, reduces evaporation and drying, resulting in greater PPP utilization and metabolism.

Any slight increase in deposition of PPP onto the target through a reduction in drift, is more than compensated through the improved presentation and metabolism of PPP deposits and the reduction in unutilized, dissipated and denatured deposits. Additionally, independent research shows that Codacide does not adversely affect the rate of disappearance of PPP residues.

Extensive three year trials were conducted by the UKs Ministry of Agriculture, Food and Fisheries (1999) on the efficacy of Codacide with pirimicarb on tomatoes in the control of *Myzus persicae* and *Tetranychus urticae*. Residue analysis of leaves and fruit using Gas chromatography (gc) analysis was conducted in three studies undertaken consecutively each year, over a three year period.

In Year One studies, associated pirimicarb residue analysis from tomato leaves and fruit indicated, that whilst there was increased initial deposition, there was no change in the rate of pirimicarb disappearance over 72 hours from the primicarb alone and pirimicarb plus Codacide applications. Pirimicarb residues detected in tomato fruit 72 hours after application with full rate Primicarb alone, was 0.03 mg/kg as compared to Pirimicarb plus Codacide at 0.04 mg/kg with official Maximum Residue Levels (MRLs) for primicarb and tomato being 1 mg/kg. At half rates – primicarb alone was 0.02 mg/kg as compared to primicarb plus Codacide at 0.015 mg/kg.

In Year Two studies, the "decay of total pirimicarb residues followed a log relationship with time after application in both leaves and fruit, but there was no reduction in the rate of decay due to the addition of Codacide". Only very small quantities of pirimicarb metabolite were detected on tomato fruits. In Year Three studies, after 72 hrs, pirimicarb residues were slightly higher in leaves treated with pirimicarb alone in contrast to the lower levels for leaves treated with pirimicarb and Codacide Oil, which also resulted with residues on fruit samples being below the limits of detection (0.001 mg/kg) (MAFF, 1999)

MAFF (1999) also undertook one study, that analyzed (using gc Gas chromatography) the surface and penetrated residues extracted after 24 hrs from the leaves of tomatoes and cabbages treated with Ambush (10% a.i. cypermethrin, E.C) and from treatments with Pirimor (50% a.i pirimicarb, W.P) with and without Codacide Oil. This found no significant differences in residue levels with treatments containing Codacide Oil.

Extensive GLP residue studies were conducted by Neotron (2000) on the determination of copper (cu) residues on tomatoes and grapes in Italy, with samples analysed in mass inorganic spectrometry (ICP-MS), with the analytic method of standard addition according to European directive 88/320/CEE. Replicated samples of grapes last sprayed 48 hrs pre harvest with Cupravit (Copper Oxychloride 750 ml/hl), were found to contain residue levels of 11.729 mg/kg verses similar residue levels found in grape samples from Cupravit (Copper Oxychloride 750 ml/hl) plus Codacide Oil (250 ml/hl) of 11.022 mg/kg. In tomatoes, residue analysis of samples treated with Ossicloruro 50 M.I (Copper oxychloride 50% WG 300 g/l) alone gave statistically similar levels of residue levels (1.001 mg/kg) as compared to Ossicloruro 50 M.I (Copper oxychloride 50% WG 300 g/l) with Codacide Oil (250 ml/hl) (Neotron, 2000).

During 2009 and 2010, the US Chemical Producers and Distributors Association (CPDA) Adjuvants and Residues Working Group (ARWG) compiled existing data from 437 studies that compare active ingredient residue levels in plants grown with and without adjuvants present under the same growing conditions ("side-by-side" studies). This effort was initiated in collaboration with the US Environmental Protection Agency (EPA) and found that adjuvants do not increase active ingredient residues to levels of concern.

Linear regression analysis showed that the overall average ratio of residue levels when adjuvants are used, to residue levels when not used is 0.90, indicating that across all variables (e.g., crop, adjuvant types, etc.) residues actually *decrease* slightly with adjuvant use. Thus, the data demonstrates that adjuvants generally do not increase active ingredient residues above levels that would be of concern to the EPA (ratios between 1 and 2) (CPDA, 2010).

Further, the US Environmental Protection Agency (EPA) has exempted the class of Codacide Oil's emulsifier constituent (Codacide is made from 95% rape seed oil and 5% emulsifier), from the requirement of a tolerance for residues and eliminated the need to establish a maximum permissible level for residues, which is also the case for Rape seed oil. Both are similarly exempted in the EU. Codacide Oil, as shown by modified sturm tests (Life Science, 1992) is readily biodegradable and does not have any metabolites, other than carbon dioxide and water and maintains no harvest interval.

III. Codacide Safeguards Integrity of Plant Protection Products (PPPs).

Codacide Oil maintains the integrity of PPPs and assists reduce factors such as volatization, evaporation, alkaline hydrolysis, UV breakdown and photodecomposition – all elements that can denature and neutralize PPPs.

Codacide Oil's ability to safeguard integrity of PPPs, is perhaps best shown by its use with with Mycoinsecticides, such as *Metarhizium*. Sp and *Beauveria basssiana* conidia that - being live biological agents, are most susceptible to denaturing and neutralization from these elements.

A Codacide oil based formulation has key advantages over water based formulations in that: hydrophobic conidia are easily suspended; conidia can be stored in oil without appreciable loss of viability (by excluding oxygen and water, thereby limiting metabolic activity and enhancing longevity); protects conidia from UV degradation (Codacide oil absorbs UV radiation and fungal conidia are protected); enhances fungal infectivity at low humidities by maintaining moist conditions (reducing dew dependence), which are essential for effective use of fungi in microbial control; and protects conidia from rain wash off. Codacide with a PH value of 7.2 also does not affect PH of spray mixtures with Wells (1989) showing that glyphosate and water (PH 4.62) was similar to Glyphosate and Codacide Oil (4.58).

CABI Bioscience studies (Alves *et al* 1998) which evaluate the survival of conidia of *Metarhizium anisopliae* exposed to UV light, proved that UV exposure delays germinantion of conidia. Alves *et al* (1998) showed that Codacide Oil significantly enhanced conidial tolerance ($P<0.05$) against UV light for up to 6 hrs of exposure, compared to water, water plus Cropspray, Cutinol, Actipron and Tween adjuvants and surfactants. Codacide Oil's natural solar filters protect conidia against UV radiation, not interfering with germination or pathogenicity.

After exposure to natural sunlight at a UVB dose of 2.2 kJ m-2, Ghajar *et al* (2007) confirmed Codacide Oil's photostabilising affect on the survival of *Plectosporium alismatis* and *Colletotrichum orbiculare* conidia. Similarly, Moore *et al* (2008) found that exposure of *M. flovoviride* conidia in water to UV for 1 hr resulted in only 4.7% germination after 24 hrs incubation, as compared to 36.5% for conidia formulated in Codacide Oil.

Conidium application under field conditions is limited by the environment that can promote moisture loss, thus limiting conidial growth and their effects. Leemon *et al* (2008) assessed the impact of evaporation and humidity loss and studied the effect of Codacide oil on *M. anisopliae* conidial germination and penetration, and observed 100 % mortality of *Boophilus microplus (cattle tick)* by 2 to 5 days post treatment. These results showed that Codacide oil provided a good interface between conidia and the arthropod cuticle, and increased conidial livability by preventing water evaporation. This was confirmed by Jenkins *et al* (1996) in assessing the efficacy of *Metarhizium flovoviride* conidia formulations with Codacide Oil in the control of locust and grasshopper populations "where the Codacide Oil component of the formulations provided greater protection of the conidia from environmental stresses".

Volatility and viscosity exert an important influence on the production of droplets and whether they will impact on their target, be it insect, plant or other surface (Barlow and Hadaway, 1974). When a water based spray is introduced into a warm and relatively dry atmosphere, much of the water evaporates out of the droplets and their size is reduced rapidly, so that a considerably lower volume than originally emitted reaches the target. Small droplets with a high surface area/volume ratio, rapidly evaporate in dry air (Maas, 1971). Once on target evaporation proceeds, resulting in dried pesticide layering and neutralized residue deposits. Codacide increases viscosity, reduces evaporation and creates a more uniform droplet size, which renders the active ingredient suitable for application with water (Alves, 1998).

Imperial College, London University (ICL, 1999) conducted extensive research to assess the affect of Codacide Oil on reducing formulation volatilities. The work evaluated the volatility of water-based formulations with different concentrations of adjuvant oils and compared volatility of these oil based and conventional water based formulations to that of Codacide Oil formulations. The results of ANOVA on the percentage of the initial weight remaining showed that Water + Codacide Oil had a low volatility and did not evaporate more than 4.5 % during 480 minutes, compared to Water + Agral which was completely evaporated after 360 minutes; Water + Shellsol T which was completely evaporated after 90 minutes; and water + Tween 80 which was totally evaporated after 180 minutes.

At Imperial College London, Codacide Oil was found to have a high viscosity (51.5 cp at 30 ^{o}C) and low volatility and the addition of 10% Codacide Oil to water increased the viscosity from 1.2 cp (pure water at 30 ^{o}C) to 1.6 cp and decreased volatility. Reduced evaporation allows effective spreading with Codacide Oil achieving complete spreading in 30 minutes on hydrophobic surfaces such as insect cuticles. The study (results of ANOVA) confirmed that 10% Codacide Oil gave the highest half life value at the lowest concentration and enhanced the infectivity of *M. Anisopliae* conidia in water based formulation on *Tenebrio molitor* larvae. This was 17 times more effective than condidia formulated in water plus Tween 80 (ICL, 1999).

Extensive three year trials conducted by the UKs Ministry of Agriculture, Food and Fisheries (1999) included laboratory experiments to measure the effect of Codacide Oil on the volatisation of insecticides. In replicated trials, Hostaquick (55% a.i. heptenophos E.C., 0.84 ml) was prepared with Codacide and without, and incubated in the dark at 25^{o}C and removed for analysis 0, 1, 2, 4, 6 and 8 hours after treatment. Heptenophos dissipation was exponential with a half life of <30 minutes when Codacide Oil was not present. When Codacide Oil was present the half life was raised to nearly 60 minutes and Codacide appeared to increase heptenophos stability, relative to the mineral adjuvant Crop oil.

Similarly, in replicated trials, Pirimor (40% a.i. dimethoate EC., 0.85 ml) emulsions were prepared with and without Codacide Oil and incubated in the dark at 25^{o}C and removed for analysis 0, 1, 3, 6, 8 and 10 days after treatment. Dimethoate dissipation was exponential with half life of 3 days when Codacide Oil was not present. When Codacide Oil was present the half life of Dimethoate was increased to approximately 4 days (MAFF, 1999).

Stathers *et al* (1993) showed that Metarhizium conidia stored in Codacide Oil for more than one week at 25 ^{o}c maintained viability. Alves *et al* (2002) showed that Codacide Oil provided good conidial germination (>98% after 24hr and 100% after 48hr) and maintained over 96% viability after more than 7 months storage at 10 ^{o}c and over 85% viability at 27 ^{o}c.

Codacide Oil's non ionic nature is advantageous because of its lack of reactivity with ions present in hard water (e.g., calcium, magnesium, or ferric ions). In contrast, other cationic surfactants or adjuvants ionise in water, such that the hydrophilic group becomes positively charged (i.e. Ethokem) and this has severe adverse affects on conidial viability. Those surfactants/adjuvants with high emulsifier content, also tended to adversely affect conidial viability, such as Output (60% mineral oil, 40% emulsifier adjuvant) (Alves *et al*., 2002).

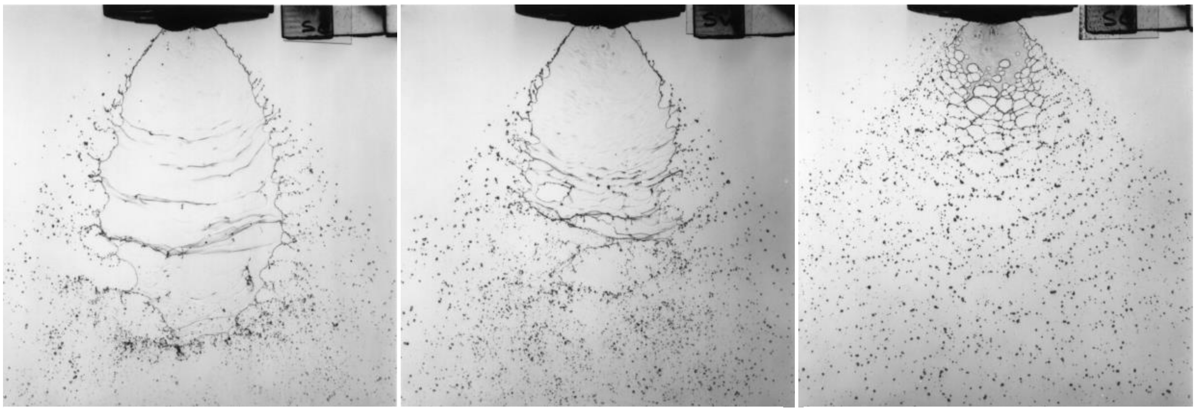
Codacide Oil allows for the conidia and oil droplets to be suspended in a continuous, aqueous phase (Polar *et al*., 2005). Fungal conidia formulated in oils have shown greater infectivity than conventional water-based suspensions (Bateman and Alves, 2000). In the laboratory, ICL (1999) has shown Codacide Oil to be non toxic and an effective carrier for *Metarhizium* conidia. The effect of Codacide Oil on the viability of *Metarhizium anisopliae* was evaluated by Alves *et al* (2002) and found that Codacide was compatible and could be used to formulate *M. Anisopliae* without any adverse affects on viability, with conidial viability being maintained above 90% at 10^{o}c after 40 weeks of medium term storage. Likewise, Luke and Thomas (2007) confirmed Codacide Oil's ability to safeguard the integrity of *Metarhizium* and *Trichoderma,* through an increased protection from evaporation, UV degradation and photodecomposition.

IV. Codacide Oil Reduces Drift:

Water has a tendency to produce a wide range of droplet sizes. Small droplets are prone to drift, and large droplets are prone to bounce and target run-off. Codacide provides the ability to attain more uniform optimum droplet sizes, that reduces the number of driftable fines (small droplets under 100 um) and the number of run-off prone large droplets (over 200 um). By improving the quality of the spray produced by agricultural nozzles, Codacide has important consequences for optimising pesticide inputs and minimising off-target contamination (Butler Ellis and Tuck, 1999).

From standard flat fan (Butler Ellis *et al,* 1997; Miller, 2006), pre-orifice, hollow cone (Butler Ellis and Tuck 1999) to low pressure, air assisted, mist blowers (Bateman *et al*, 2005; Bateman and Alves, 2000), even spray (Hollaway *et al* 2000) to Ultra Low Volume (ULV) and Controlled Droplet Application (CDA) (Alves *et al*, 2000; Leemon and Jonsson, 2008; Bateman *et al* 2000; Dobson, 1986), Codacide improves droplet uniformity, Volume Median Diameter (VMD) and reduces driftable fines and the creation of large run off prone droplets.

Fig. 1: Spray Sheet Length with Standard Flat Fan Nozzle.



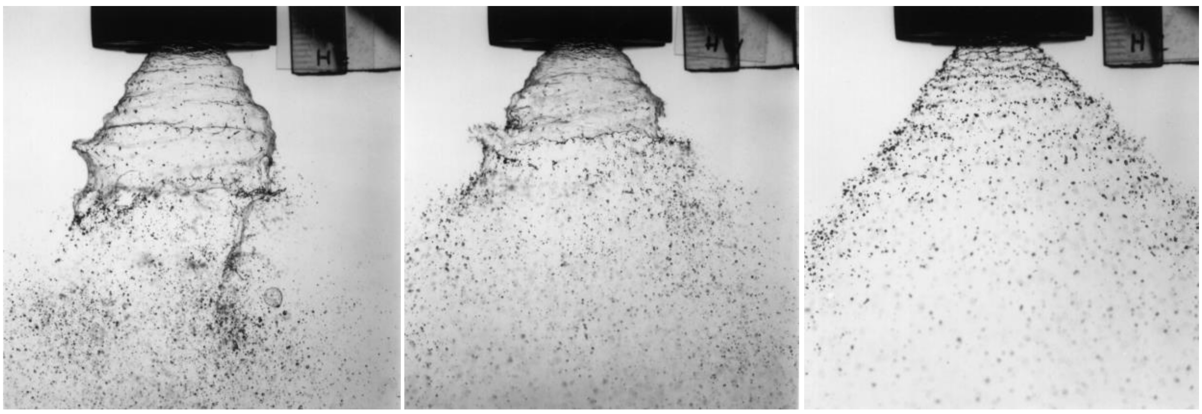
Standard flat fan nozzle spraying 0.5% Ethokem at 1.0 bar

Standard flat fan nozzle spraying Water at 1.0 bar

Standard flat fan nozzle spraying 1.0% Codacide at 1.0 bar

Butler Ellis and Tuck (1999) investigated the influence of seven spray liquids (water alone and water plus one of six adjuvants) on five different hydraulic nozzles (standard flat fan, pre-orifice, hollow cone, low pressure and evenspray nozzles). Codacide significantly reduced the liquid sheet length as compared to water alone and water plus the other six adjuvants (*fig 1,2 & 3*).

Fig 2: Spray Sheet Length with Hollow Cone Nozzle.



Hollow cone nozzle spraying 0.5% Ethokem at 1.5 bar

Hollow cone nozzle spraying water at 1.5 bar

Hollow cone nozzle spraying 1% Codacide at 1.5 bar

Codacide achieved liquid sheet break up through perforation, rather than though oscillation, as was found with the two water soluble surfactants Agral and Ethokem. Early sheet breakup caused by Codacide resulted in a higher droplet Volume Median Diameter (VMD) and less drift prone fines (*fig 4*). In addition, droplet velocities were found to be higher with Codacide where perforation was the mechanism of spray formation, than when sheet oscillation was the predominant mechanism (Butler Ellis and Tuck, 1999).

Fig 3: The effect of different adjuvants on the length of the liquid sheet produced by five hydraulic nozzles

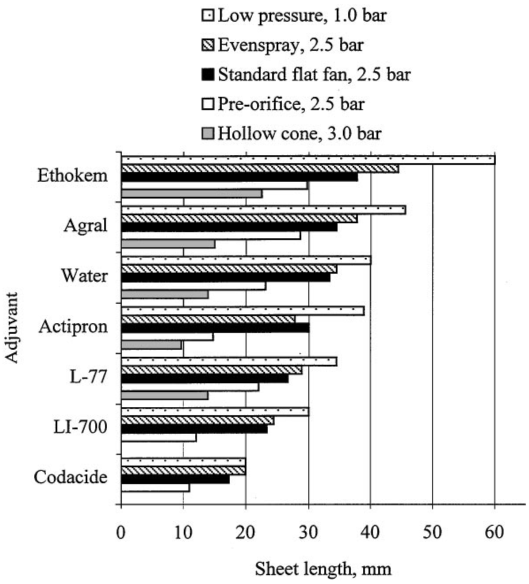
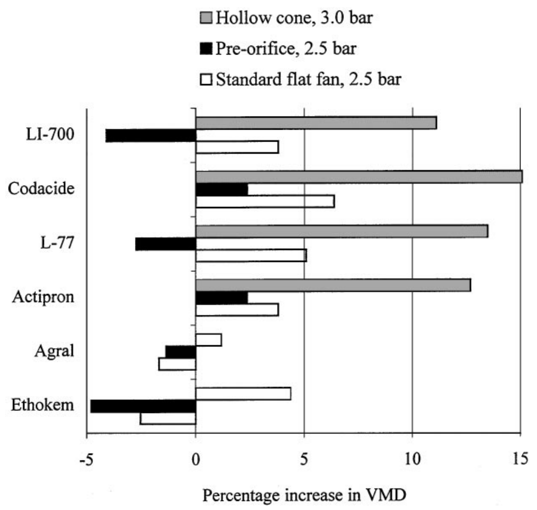


Fig 4: % increase in VMD for three hydraulic nozzles

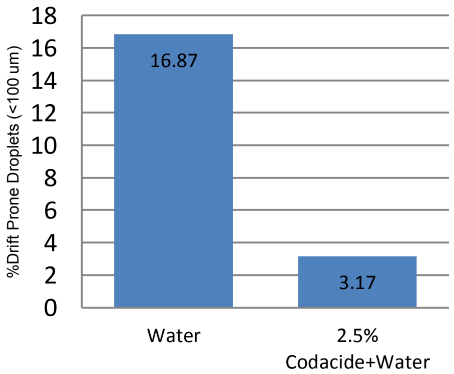


The effect of adjuvants on the risk of spray drift depends on both the droplet size and velocity. Larger optimum sized droplets travelling faster reduce the potential for spray drift. Similarly, smaller slower moving droplets increase the potential for spray drift. Spray drift declines with increasing droplet size and velocity (Western *et al.*, 1999).

Butler Ellis *et al* (1997) showed how Codacide Oil influenced not only droplet sizes (by increasing VMD and decreasing drift prone fines), but also droplet velocity. Using an optical shadowing device comprising a 2D-GA1 optical array imaging device, the droplet mean liquid velocity (ms-1) of water plus Codacide was 7 ms-1 versus only 5.2 ms-1 for water alone.

Fig 5: Measurement of Drift Prone Droplets through Conventional Nozzles

Three replications with 1000 scans in each replication eg Flat Fan Nozzle (Lurmark 03 F110/1.2/3) at 3 bar pressure



International Pesticide Application Research Centre (IPARC), University of London

Hollaway *et al* (2000) found that Codacide Oil reduced the Small Droplet Component (SDC) of drift prone droplets from 44.8% for water alone and 33.7% for the mineral oil Actipron to 26.7% for Codacide using Phase Doppler Particle Analyser (PDPA) and increased the Volume Median Density (VMD) considerably as compared to water alone to achieve greater consistency of optimum droplet sizes for efficient spraying.

Miller (2006) found that Codacide Oil improved the performance of flat fan nozzles by reducing percentage of driftable spray fines by over 4% as compared to water alone. In contrast the adjuvant Ethokem increased the percentage of spray fines by over 2%.

Mathews and Barnett (1991) used Laser Particle Analysis to measure the sizes of droplets produced through a range of conventional hydraulic nozzles at different pressure settings, with and without Codacide. Codacide was found to reduce the proportion of drift prone droplets by an average of 79% (fig 5).

Addition of 1% v/v Codacide Oil with glyphosate (Roundup Biactive) for municipal areas weed control sprayed using conventional nozzles produced a sharper definition of the sprayed swath. This was consistent with the measurement of a significantly lower percentage of driftable droplets (fines), as compared to identical treatments applied without Codacide (Nazer, *et al.,* 2000).

At the UK Silsoe Research Institute, Miller *et al* (1995) confirmed that for three sizes of conventional flat fan nozzle, Codacide (1% v/v) reduced the percentage of drift prone droplets. For example (<100 um for F110/0.4/3.0 nozzle), from 13.5% for water alone to 6.3% for water+Codacide, as compared to 14.9% for water+Agral (non-ionic wetting agent), 19.1% for water+Ethokem (cationic surfactant), and 11.4% for water+Axiom (mineral oil adjuvant). Volume Median Diameters (VMD) was increased with Codacide oil and uniformity of droplet spectra was improved to reduce not only small drift prone droplets, but also the large “bounceable” droplets.

Being non volatile, Codacide Oil can be beneficially used to obtain the narrowest droplet size spectra (usually between 80-150 um that is necessary for ULV spraying) and maximizes the volume of droplets in the optimum range when using ULV rotary atomizers such as the “Micronex” (Bateman and Alves, 2000). Whilst this is not possible with water formulations alone, due to its high evaporation rate, Codacide increases ULV spray quality within narrowly defined droplet spectra that allows large areas to be treated with relatively small volumes of liquid (Leemon and Jonsson, 2008). In addition, non-evaporative oils, such as Codacide, limit the diminution in droplet size during flight (Bateman *et al*, 2000).

Table 1: Effects of the equivalent application volume rate (VAR) on the spray characteristics of an emulsifiable oil – based formulation and an oil based formulation:

Formulation	Flow Rate (ml/m in)	Peristaltic pump speed setting	Equivalent VAR (l/ha)	VMD (um)	Relative Span	Est. droplet volume (pl)	Est. no. conidia per droplet
Water plus Codacide 10%	0.5	9	0.3	87.69	2.38	471.44	1473.28
	1.5	90	1.0	77.85	0.40	242.85	242.35
	4.8	54	3.2	107.63	0.63	655.13	204.78
	15.1	99	10.0	110.49	0.70	710.44	71.04
50% Shellsol T plus 50% Ondina EL	0.5	14	0.3	67.91	4.43	167.87	524.58
	1.5	49	1.0	73.48	0.33	207.83	207.83
	4.8	71	3.2	75.19	0.49	222.66	69.58
	15.1	90	10.0	80.81	0.75	273.82	27.38

Alves *et al* (2000) compared Codacide to Ondina El and Shellsol (Refined paraffinic oil adjuvants) conidial formulations (with *Metarhizium anisopilae*), to assess droplet production characteristics. The droplet size spectra was assessed by spraying the formulations with a spinning disc atomizer, fitted in the cabinet of a Malvern Particle Size Analyzer, to analyze the influence of both formulations with and without conidia on droplet size, droplet distribution and droplet volume.

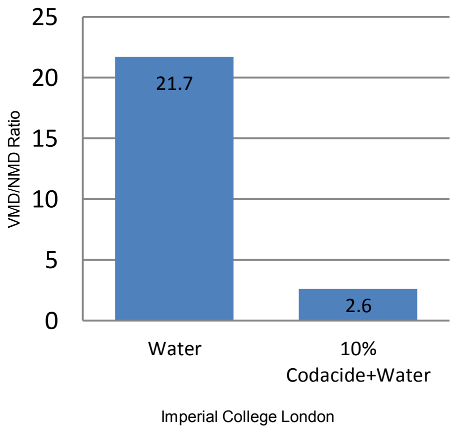
Alves *et al* (2000) showed that Codacide Oil significantly assisted secondary pick up of *M. anisopliae conidia* by the dessert locust (*Schistocerca gregaria*). In contrast to 50% Shellsol and 50% Ondina mineral oil formulations, just 10% Codacide Oil and water formulations resulted in optimum droplet sizes (VMD) between 75-150um (CDA application) compared to 50-100um for mineral oils. Reduced driftable spray fines and increased VMD of droplet sizes, also resulted in the Codacide Oil formulation having greater droplet volumes and number of estimated conidia per droplet, and significantly larger estimated mean numbers of conidia per cm^2 than mineral oil formulations when applied by spinning disk atomizer. Greater coverage and more effective deposition of conidia on the plant surface (wheat) enhanced secondary pick up by insects.

As indicated in Table 1, VMD were increased by the addition of Codacide as compared to the Paraffinic Oil formulations Shellsol and Ondina, reducing not only susceptibility to drift but also increasing droplet volume and estimated number of conidia per droplet.

Codacide's ability to reduce the proportion of driftable fines was confirmed by Bateman *et al* (2000) who assessed Codacide oil emulsions against Agral (non ionic wetting agent) emulsions with and without *Beauveria bassiana* conidia through a standard Cooper Pegler hollow cone nozzle. Codacide increased the VMD at all nozzle pressures (100, 200 and 300 kPa). For example, from between 39-60 um at 300 kPa, the VMD of droplets prodcued represented a 2 to 3 times increase in the quantity of droplet volumes, and is commensurate with a substantial reduction in driftable fines.

Fig 6: Measurement of Control of Droplet size through a Rotary Atomizer CDA System

Each of the bar charts presents the mean of 3 tests, with 1000 scans in each replication



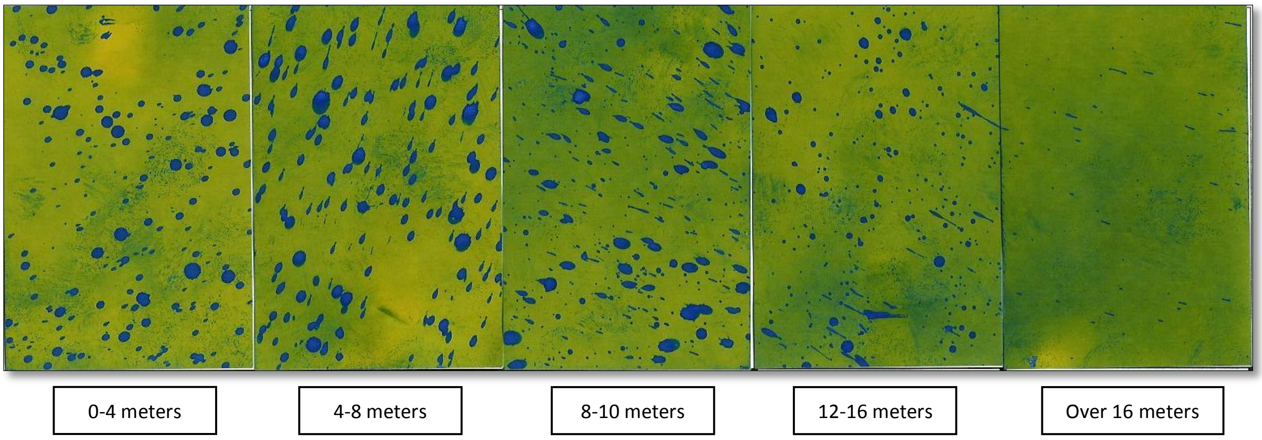
Providing greater control over droplet size to achieve enhanced uniformity of optimum droplet size was shown through research conducted on Codacide at Imperial College London. Dobson (1986) investigated droplet size uniformity produced through a CDA rotary atomizer with a 10% Codacide solution, compared to water, as measured by VMD/NMD ratio (when all droplets are the same size, the VMD/NMD ratio = 1). As indicated in Figure 6, Dobson found that with Codacide the droplet spectra produced was some 80% more uniform than that produced by water alone.

Farm field trials conducted in Hungary by the Agricultural Office of County Fejer, Plant Protection & Soil Conservation Directorate (PPSCD) showed clearly how the use of Codacide with the dessicant Reglone Air in aerial spraying application significantly reduced drift (Palmai and Gyulai, 2009 a. b.).

Fig. 7: Distribution of droplets examined from the middle of the track of helicopter. Reglone Air + Mist Control (drift reducing adjuvant) 2 ltre per ha + 5% v/v

0-4 meters | 4-8 meters | 8-10 meters | 12-16 meters | Over 16 meters

Fig. 8: Distribution of droplets examined from the middle of the track of helicopter. Reglone Air + Codacide Oil 2 ltre per ha + 2 ltre per ha



As seen in the drift sensor flats depicted in Fig. 7 and Fig. 8, Codacide Oil reduced drift significantly more than the drift reducing adjuvant "Mist Control" with no drift of droplets over the working width. In addition, Codacide Oil eradicated any deformity of droplets due to slip stream affect associated with aerial application. In contrast, 2-3 meter drift outside the working width was observed with Mist Control and as shown in Fig. 7 drops became elongated and deformed due to the affect of slip stream towards the outer edge of the working width. As a result, the Hungarian PPSCD authorizes Codacide aerial spraying with a much smaller buffer zone as compared to Mist Control (Palmai and Gyulai, 2009 a.b.).

V. Codacide Oil Confers Rainfastness

The occurrence of rain or dew after spraying Plant Protection Products (PPP) constitutes one of the greatest losses to spray deposits and subsequent reduction in efficacies. Codacide Oil can substantially enhance the sticking tenacity of PPPs, conferring on them a high degree of rainfastness (Covarelli and Pannacci, 2009).

Table 1: ED_{50} dose (g ai ha^{-1}) of tribenuron-methyl (alone and in a mixture with Codacide), subjected to different rain treatments on *Tripleurospermum inodorum*.

Rain Treatment	No Adjuvant	Codacide Oil
	ED_{50} dose (g ai ha^{-1}) of tribenuron-methyl alone	ED_{50} dose (g ai ha^{-1}) of tribenuron-methyl + Codacide
No Rain	0.38 (0.047)	0.20 (0.022)
Rain at 1 HAT	9.48 (1.219)	2.48 (0.275)
Rain at 2 HAT	5.89 (0.699)	1.34 (0.147)
Rain at 4 HAT	4.43 (0.523)	0.57 (0.063)

Note: Standard errors are in parenthesis (P=0.05). HAT, hours after treatment.

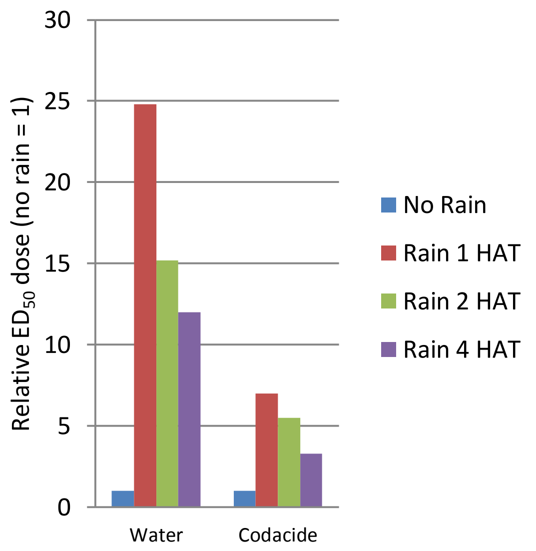
Pannacci *et al* (2010) showed that Codacide Oil not only enhanced the performance, but also improved the rainfastness of tribenuron-methyl (post emergent herbicide) on broadleaved weeds. In studies conducted at the Department of Agricultural and Environmental Sciences, University of Perugia, Italy; and Department of Integrated Pest Management, Aarhus University, Denmark, in three replicates - groups of plants were subjected to 3 mm of rain at 1, 2, and 4 hours after treatment (HAT).

In order to separate the effect of Codacide that was caused by improved activity and that which was caused by true rainfastening, the ED_{50} doses of the rain treatments were expressed relative to the ED_{50} dose of the corresponding no-rain treatment.

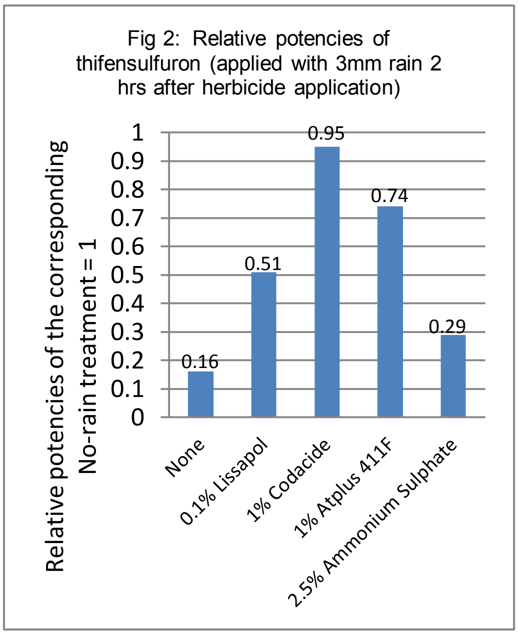
As seen in Fig 1, the adverse affect of rain was significantly more pronounced on tribenuron-methyl applied alone with water as compared to when applied with Codacide (0.87% v/v).

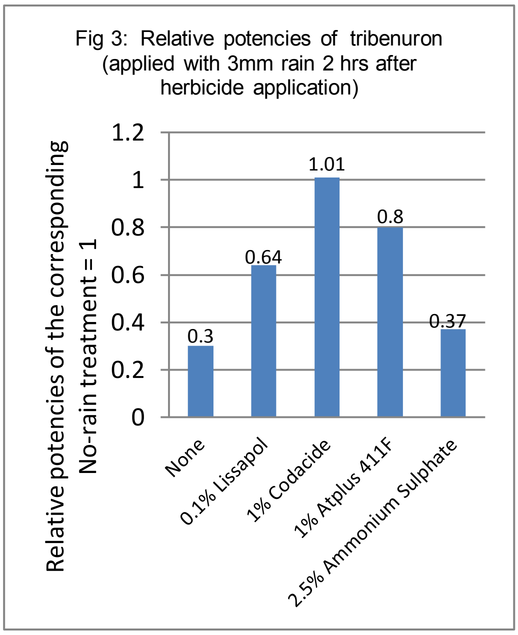
The Danish Institute of Plant and Soil Science (Kudsk, 1992) showed in four experiments, with two rainfall intensities, that Codacide Oil significantly increased the rainfastness of thifensulfuron and tribenuron (short-residual sulfonylurea herbicides).

Fig 1: Relative ED_{50} dose tribenuron-methyl (water alone and with Codacide) subjected to 1,2 and 4 h after treatment (HAT) on *Tripleurospermum inodorum*



Full rainfastness was obtained 2 h after application in a tank mixture with Codacide Oil. As compared to other adjuvants (Atplus 411F, Lissapol, etc) only with Codacide Oil was no significant reduction in herbicide activity observed by rain 2 hr after spraying (refer Fig. 2 & 3).

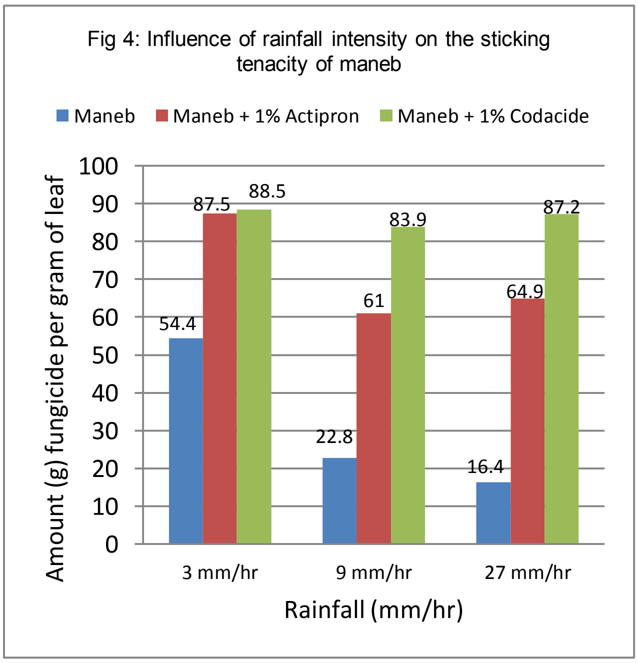


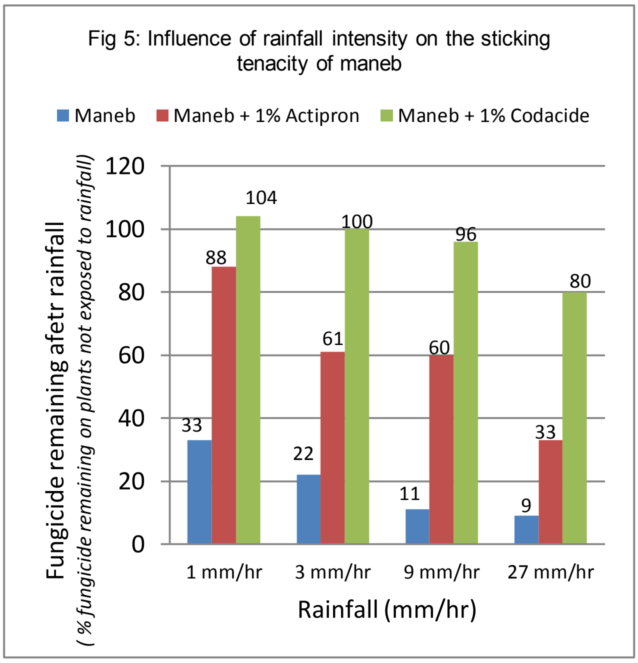


In assessing the effect of adjuvants on the rainfastness of Thiameturon and DPX-L5300, Kudsk (1990) found that maximum rainfastness was obtained by Codacide Oil and that full rainfasness was achieved 2 hours after application of the herbicides.

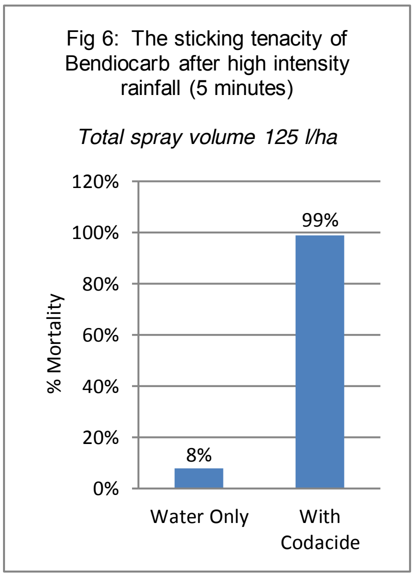
Kudsk, Mathiassen and Kirknel (1991) found that Codacide Oil significantly increased the rainfastness of the fungicide maneb (WP and SC formulations) on pea. As shown in fig. 4 & 5, better rainfastness was observed with Codacide Oil than with the mineral oil adjuvant Actipron. At all rain volumes, significantly more maneb WP was retained on the plants with Codacide Oil, than with Actipron.

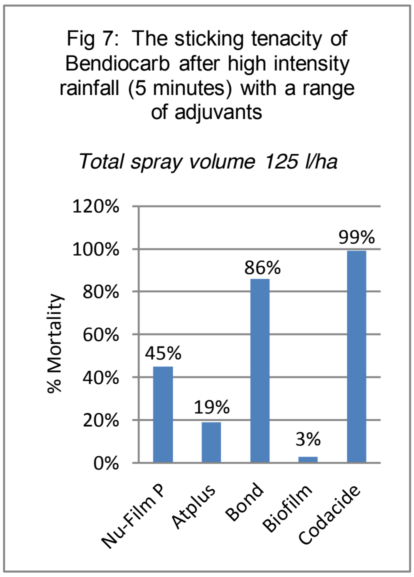
A significant effect on the rainfastness of maneb SC was only observed with Codacide Oil. Only Codacide Oil (as compared to Actipron, Spraymate Bond, Nufilm-P) eliminated the effect of rain intensity and enhanced the resistance of the SC formulation of maneb to wash-off. Codacide Oil can protect the spray deposit against the mechanical impact and removal from rain droplets (Kudsk, Mathiassen and Kirknel, 1991). Hidalgo *et al* (2003) also found that Codacide conferred improvements in rainfastness to copper fungicides in trials conducted by CABI Bioscience, UK, against *Moniliophthora roreri* in cocoa.

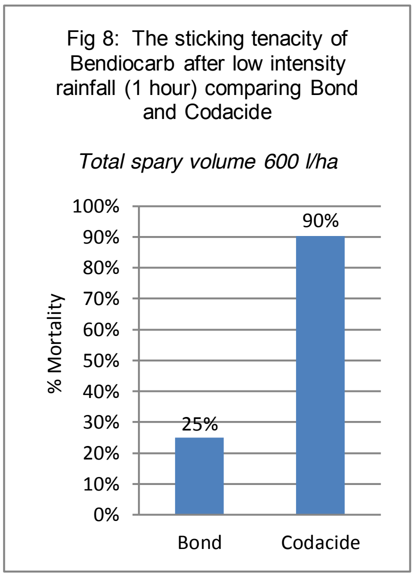




Taylor and Mathews (1986) illustrate the rainfastness conferred on the insecticide bendiocarb using Codacide Oil on brassicas. Bendiocarb was applied at a volume of 125 l/ha and subjected to high intensity rainfall for five minutes. Bendiocarb was applied alone, with Codacide and with a range of other adjuvants. Codacide Oil caused a significant level of improvement in the rainfastness of bendiocarb. Mortality rates in plots sprayed with Codacide averaged 99% after five minutes high intensity rainfall compared to only 8% control in water only plots (refer fig.6 & 7).

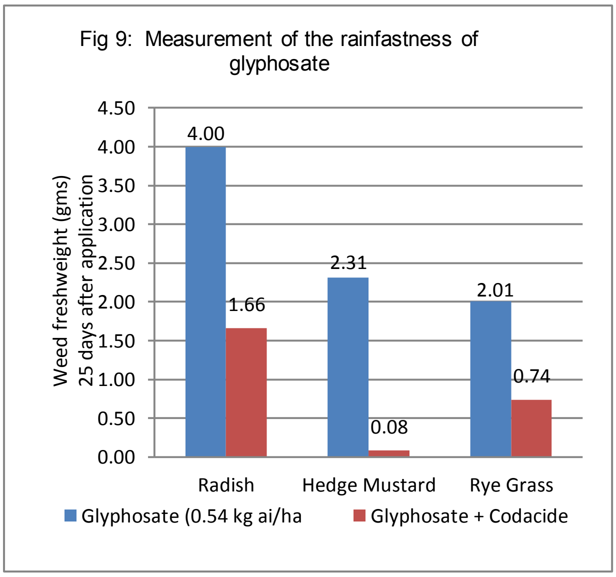


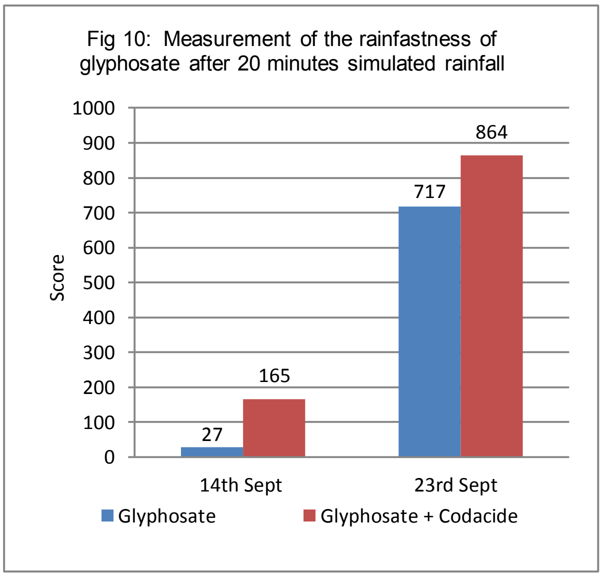




Bendiocarb was also applied at a volume of 600 l/ha and subjected to 1 hour of low intensity rainfall with Bond and Codacide adjuvants. Mortality rates in plots sprayed with Codacide averaged 90.3% after 1 hour of low intensity rainfall compared with only 25% control in plots sprayed with Bond (refer fig 8.). Within a few minutes of being applied, Codacide significantly improved the adhesion of the insecticide to the target in both high and low intensity rainfall.

Rain and dew free periods of at least six hours is required for maximum efficacy for one of the world's most widely used herbicides glyphosate (The UK Pesticide Guide, 2010). Wells (1989) showed that Codacide Oil reduced Glyphosate susceptibility to rainfall occurring in this critical six hour post spraying period.





Prolonged medium intensity rainfall (5-6 mm/hr for a duration of 1 hr) was applied to a range of weed species (Radish, Hedge Mustard, Rye Grass) at intervals of 1, 3 and 6 hrs after application. As depicted in Fig. 9, Codacide Oil significantly (P<0.05) enhanced glyphosate activity on ryegrass, hedge mustard, and radish even though rain fell 1, 3 and 6 hrs post spraying compared with glyphosate alone.

Silsoe College, Cranfield University, UK, measured the effectiveness of Roundup (glyphosate) to oilseed rape and barley plants when subjected to 20 minutes rainfall intensity with and without the addition of Codacide (refer Fig. 10). Codacide significantly enhanced the control of oilseed rape and barley to Roundup when subjected to the simulated rainfall through enhancing rainfastness (Murfitt, 1996).

Table 2: Effect of rain-free period and adjuvants on the efficacy of glyphosate applied at 720 g/ha on Annual Ryegrass (*Lolium rigidim)* Fresh wt. (g/pot) 31 days after application.

Adjuvant (% *v/v*)	**Annual Ryegrass (Lolium regidum) Fresh wt. (g/pot)**			
	Rain applied 1 hr after application	**Rain applied 2 hr after application**	**Rain applied 4 hr after application**	**No Rain**
No Adjuvant	8.91	11.45	9.96	2.27
Pulse (0.5)	8.86	5.00	5.86	0.76
Teric 17A3 (1.0)	7.52	8.54	4.50	1.23
Surfynol 465 (0.5)	10.81	10.29	5.96	1.91
SST Rainfast (1.5)	8.60	6.70	4.71	0.57
Codacide (2)	6.69	5.98	4.05	0.13
Bondcrete (0.5)	11.49	8.21	3.82	0.23

Combellack *et al* (2001) assessed the effect of simulated rainfall and selected adjuvants on the herbicidal performance of glyphosate. As shown in Table 2, Codacide gave significantly improved control (at 2% *v/v*) with glyphosate 720g/ha in pot trials on Annual Ryegrass (*Lolium rigidim*), when no rain, as well as for 1 hr, 2 hr, and 4 hr after spray application (when 30 minutes of 5mm/per hr simulated rainfall) was applied.

In field trials conducted by University of Queensland Gatton College (1990) Codacide was shown to confer good rainfastness to glyphosate (Roundup CT) on barley cover crop which was selected as it has a densely structured epicuticular wax which is difficult to wet and thus a good test species to assess the effective properties of Codacide Oil.

VI. Codacide Oil Increases Adhesion and Retention:

The efficacy of spray retention by targets depends mainly on the velocity and size of the impacting droplets and their intrinsic physico-chemical properties and those of the target surface. In addition to improving velocity and optimum droplet size uniformity (refer Section. IV.), Codacide Oil's physico-chemical properties are of a similar composition to leaf and insect cuticle wax (both are triglycerides) which assists adhesion and retention efficacy.

Holloway *et al* (2000) examined adjuvant effects on fluorescein retention by field bean, pea and barley foliage after application with an even spray nozzle. This showed that Codacide Oil (10 g l^{-1}) with a Deposit per Unit Emission (DUE) mean of 2,703 increased retention by over 41% compared to water alone (DUE 1909) and some 20% more than compared with the mineral oil Actipron.

Table 1: Ajuvant effects on fluorescein retention by field bean, pea and barley foliage after application with an even spray nozzle.

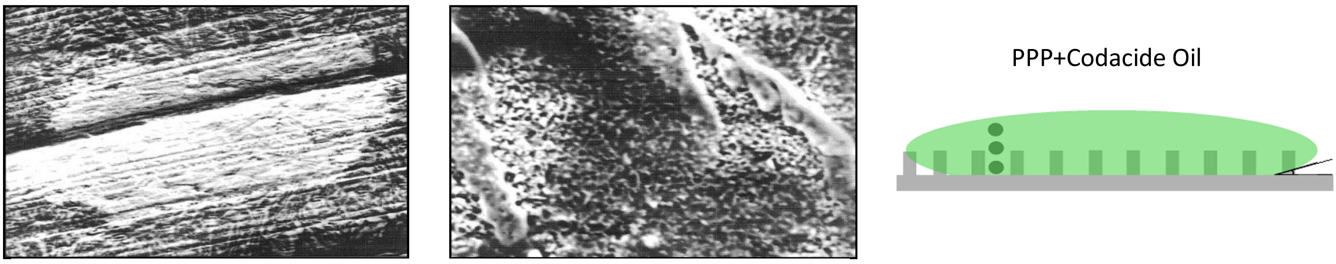
Additive	Mean Deposit per Unit Emission (DUE) Values [a]		
	Field Bean	Pea	Barley
None	7.41 (1657)	4.80 (121)	4.88 (131)
Actipron	7.58 (1961)	5.34 (208)	5.01 (149)
Codacide Oil	7.57 (1931)	6.24 (513)	5.56 (259)

Note: [a] In values for statistical analysis; back-transformed values in parenthesis

As seen in Table 1, Codacide ability to improve adhesion and retention is especially apparent for hard-to-wet foliage such as young barley foliage (due to their dense covering of microcrystalline epicuticular wax), and for waxy, water repellent surfaces of pea foliage than for the easily wettable foliage of field beans (Holloway *et al*, 2000).

Balsari *et al* (2001) at the University of Torino, Italy, also showed how Codacide improved adhesion and retention on different vine cultivars (Moscato, Pinot Nero and Barbera) especially for cultivars with a higher presence of hairs on the leaves (Pinot Nero and Barbera) with a 17% and a 27% increase for Pinot Nero and Barbera consecutively compared to pure water alone on the upper leaf surface of vine cultivars (as determined by spray deposit ul/cm^2).

Fig. 1: Droplet of chlormequat applied with Codacide on wheat



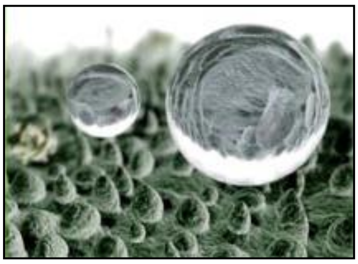
Amorphous state of Codacide maintained and microcrystalline finger-like protrusions of epicuticular wax penetrated for improved interface, adhesion and retention.

Small droplet contact angle and strong interface with PPP available for target surface interaction.

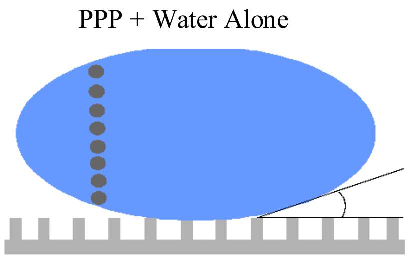
As examined by Scanning Electron Microscope (refer Fig. 1), droplets applied to wheat leaves (using Hamilton Syringe) that contained Codacide and the growth regulator chlormequat were found to maintain their amorphous state and find their way past the finger-like protrusions of microcrystalline epicuticular wax forming a solid interface and bond between the physico-chemically similar target surface and Codacide to improve adhesion and retention (Baker, 1994).

In contrast, Plant Protection Products (PPP) applied with water alone have a greater tendency to exacerbate a hydro-phobic interface between PPP deposits and the epicuticular leaf or insect covering. This is especially pronounced for hard to wet waxy targets (i.e. *brasicas*) or targets maintaining cuticular micro protrusions (i.e young barley foliage). Higher Dynamic Surface Tensions (DFT) and resulting increased contact angles create more spherical droplets and a poor target/PPP deposit interface resulting in reduced adhesion and retention (refer Fig.2).

Fig. 2: Plant Protection Products (PPP) applied with water alone:



PPP applied with water alone have a greater tendency to exacerbate a hydro-phobic interface between PPP deposits and the epicuticular leaf or insect covering



High droplet contact angle with weak interface and low PPP to target surface area contact ratio

Mac Manus *et al* (2002), in conducting over 20 experiments at Australia's Queensland Plant Protection Unit in partnership with Queensland University on the fungicide Acrobat MZ for Onion downy mildew control, confirmed that the use of Codacide Oil resulted in a much stronger systemic activity than when non ionic wetters such as Top Wet, Nufilm and Tween 80 were used. The improved systemic activity resulted in reduced leaf lesions and also allowed the chemical to exert a strong anti-sporulation effect (refer Table 2).

Table 2: The effect of spray adjuvants on the efficacy of Acrobat MZ (2 g/l) when sprays were applied 2 days after inoculation.

Treatment	% leaf area affected by lesions	% plants with Sporulation
Acrobat MZ	28	34
Acrobat MZ + Top Wet (0.2 ml/l)	31	44
Acrobat MZ + Tween 80 (0.2 ml/l)	30	37
Acrobat MZ + Codacide (3 ml/l)	10	15
Acrobat MZ + Nu Film (0.3 ml/l)	24	63
Unsprayed Control	44	87

The waxy bloom on the surface of onion leaves is due to minute rods and platelets of wax that are responsible for their hard to wet nature and Codacide was shown to be necessary for spray droplets to adhere and spread over the leaf surface. As shown in Table 2, Codacide enabled greater adhesion and retention of Acrobat MZ and the uptake of its systemic dimethormorph molecule (Mac Manus, *et al* 2002).

Codacide Oil's reduced Dynamic Surface Tension (refer Section VII.) and its natural physico-chemical properties that are akin to the cuticular wax of the targets, assists adhesion and retention (Baker, 1994). The improved rainfastness conferred by Codacide Oil to PPP deposits, also supports the greater sticking tenacity of Codacide and increased adhesion and retention obtained (refer Section V).

VII. Codacide Oil Enhances Spreading and Coverage:

The UK Ministry of Agriculture, Fisheries and Food and Bristol University's Long Ashton Research Station assessed the affect of adjuvants on the spreading and coverage of aqueous sprays on foliage of barley and peas (MAFF, 2000). Deposit counts and mean deposit areas provided an estimate of adjuvant coverage performance in terms of the number and sizes of spray droplets retained, together with a measure of their subsequent spreading and / or coalescence.

Table 3: Adjuvant effects on the spray coverage of pea leaves after application with an even spray nozzle.

Additive	Mean Deposit Count (MDC) (for 500 mm^2)	Mean Deposit Area (MDA) (mm^2)	Coverage (% leaf area)$_a$
None – Water alone	79	0.02	1.12 (0.3)
Actipron Mineral Oil	500	0.08	1.91 (6.7)
Codacide Oil	592	0.13	2.60 (13.4)

Note: [a] In values for statistical analysis; back-transformed values in parenthesis

As summarized in Table 3, Codacide Oil (10 g l $^{-1}$) improved coverage performance on pea leaves by assisting to optimize the number and size of spray droplets with a 592 Mean Deposit Count (MDC), a coverage of 0.13 mm^2 Mean Deposit Area (MDA) per droplet representing 13.4 % leaf area on spray coverage of pea leaves as compared to water alone of 79 MDC, 0.02 MDA, and 0.3 % leaf area coverage; and as compared to mineral oil Actipron of 500 MDC, 0.08 MDA, and 6.7 % leaf area coverage.

Similarly, Codacide Oil significantly increased the coverage performance on barley leaves as compared to water alone and the mineral oil Actipron (refer Table 4). Codacide not only assists spray performance in terms of number and size of spray droplets but also improves spread of droplet on impact as compared to water alone and mineral oil Actipron (MAFF, 2000). Baker (1994) showed how the spread of the growth regulator chlormequat on wheat leaves was increased by an average of 8-9 times by the addition of Codacide.

Table 4: Adjuvant effects on the spray coverage of barley leaves after application with an even spray nozzle.

Additive	Mean Deposit Count (MDC) (for 200 mm^2)	Mean Deposit Area (MDA) (mm^2)	Coverage (% leaf area)$_a$
None – Water alone	21	0.02	-1.44 (0.2)
Actipron Mineral Oil	156	0.05	1.25 (3.5)
Codacide Oil	217	0.12	2.56 (13.0)

Note: [a] In values for statistical analysis; back-transformed values in parenthesis

Droplet spreading is influenced greatly by the surface tension of the liquid applied (Holloway *et al*, 2000). Surface tension and contact angle are important as the surface tension influences droplet spectrum and retention, whilst the contact angle indicates the degree of spread of droplets (refer Fig 1 & 2). As seen in Fig. 3 & 4, Codacide plus PPP forms a thin amorphous film that envelopes the stomata (Fig. 3) and their individual guard cells on wheat leaves (Fig. 4).

Codacide Oil and Glyphosate had a lower surface tension (0.037 Nm^{-1}) and contact angle (53^o) than Water and Glyphosate (0.048 Nm^{-1}) and (66^o) respectively (Wells, 1989). Dynamic Surface Tension (DST) values at a surface age of ca 50 ms were recorded by Holloway *et al* (2000) that showed Codacide to have a significantly reduced DST of 59 mNm $^{-1}$, as compared to the mineral oil adjuvant Actipron of 69 mNm $^{-1}$ and of water of 71 mNm $^{-1}$.

Devendra *et al* (2000) showed that the surface tension of water was reduced from 73 mN/m to 60 mN/m and the droplet contact angle reduced from 55^{o} to 30^{o} by the addition of Codacide Oil in *Oxalis latifolia* on adaxial leaf surface.

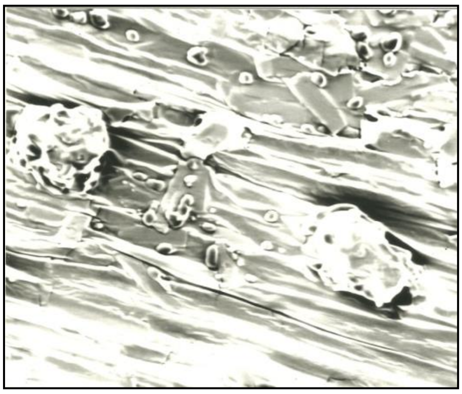


Fig. 3: Codacide plus Glyphosate forms a thin amorphous film that envelopes the stomata (Mag.X235)

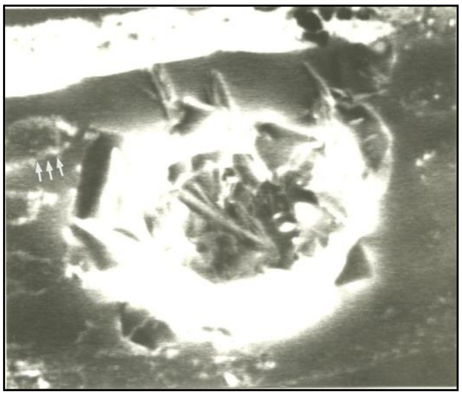


Fig. 4: Codacide plus Glyphosate at Mag X 450 forms a thin amorphous film over guard cells

Codacide Oil reduced the Static Surface Tension (SST) of maneb and mancozeb fungicide spray solutions from 60-70 mNm^{-1} to 30-40 mNm^{-1}. Reduced SST can increase deposition, especially on plants that have a well-developed epicuticular wax layer, such as pea and brussel sprouts (Kudsk, Mathiassen and Kirknel, 1991).

In assessing the influence of adjuvants on efficacy of different herbicides, Devendra *et al* 2004, determined that Codacide Oil significantly reduced the surface tension of water from 73 mN/m to 65.6 mN/m at 0.5% v/v concentration.

Alves *et al* (2001) assessed the spreading and effectiveness of Codacide Oil fungal formulation, as compared to standard water plus Tween fungal formulation. Aerial conidia of *Metarhizium anispliae* were formulated and applied on silicone treated papers to measure spreading and applied to *Tenebrio molitor* larvae to calculate the average survival time.

Comparisons of droplet spread rates after application, showed that 30 minutes were adequate for maximum spread for Codacide Oil. Codacide Oil significantly increased the spread of droplets, as compared to standard water and Tween, at all concentrations. For example, 15% Codacide giving approximately 2.9 mm droplet median diameter as compared to 1.2 mm. When the concentration of Codacide Oil was increased, spreading also increased. Concentrations of Codacide Oil between 5% and 25% also enhanced fungal infectivity more than water plus 0.05% Tween 80 (Alves, *et al*., 2001).

Alves *et al* (1998) maintains that insect cuticles and fungal conidia have water repellent properties, but Codacide Oil is rich in triglycerides similar to the insect cuticle. When the conidia are mixed with Codacide Oil there will be more affinity for the condia to stick to the insect cuticle. Conidia mixed with Codacide Oil spread on the insect cuticle further than an equivalent volume of water or water plus Tween 80 droplet. Therefore, the proportion of conidia in contact with the insect cuticle is higher than without Codacide Oil (Alves *et al*., 1998).

VIII. Codacide Oil Improves Uptake and Optimizes Efficacy of Plant Protection Prodcuts (PPPs):

By improving the delivery of PPPs (improved integrity-refer Section III, drift control-Section IV, rainfastness-Sect, V) and their effective presentation to targets (improved adhesion and retension - refer Section VI, improved spread and coverage-refer Section VII) Codacide Oil facilitates improved uptake and extends efficacy of PPPs.

During a three year study, the UK's Ministry of Agriculture, Food and Fisheries assessed the effect of Codacide Oil on the uptake of Dimethoate into the leaves of tomato, cabbage and wheat using Gas chromatography (gc) analysis and found that Codacide increased both the rate and amount of uptake into all three leaf types (MAFF, 1999).

Likewise, Baker (1985) showed that the uptake of Chlormequat chloride in the presence of Codacide Oil was greater than with the standard water based application over 96 hrs following application. This effect was most significant during the initial 24 hr period following application, when the average uptake with Codacide Oil was 97% of the dose recovered compared to an uptake of 67% with the standard application. The addition of Codacide Oil lowered surface tension and contact angles, with increased deposition and adhesion of droplets. Codacide Oil increased deposit spread by a factor of 8-9 and maintained Chlormequat chloride in its amorphous form (Baker, 1994).

Similarly, the UK's East Malling Institute of Horticultural Research (EMIHR, 1988), assessed the foliar uptake and distribution of Carbaryl on apple leaves. Apple leaves were treated under laboratory conditions with labelled carbaryl to compare the adjuvants Codacide with the wetter/spreader Agral. After one hour the leaves were rinsed with acetone removing the carbaryl which had not yet entered the surface wax. It was shown that Codacide greatly improved the distribution and uptake of Carbaryl with "only 13% of the applied Carbaryl and Agral entered the leaf between 1 and 24 hours after being on the surface; if Codacide was present 26% would enter the leaf in the first hour".

Table 1: Summary of Crops trialed and used with Codacide Oil and Plant Protection Products

Apples	Cotton	Loganberries	Roses
Amenity	Cucumber	Lucerne	Salads
Aubergine	Cyclamen	Maize	Sisal
Barley	Daffodils	Mango	Sour Cherries
Bay Trees	Date Palms	Mange Tout	Soya Bean
Bedding Plants	Eggplant	Melons	Snow Peas
Beetroot	Field Beans	Oats	Spring Barley
Blackcurrants	Forestry	Olive	Spring Oats
Bracken	Fremartia	Onions	Spring Rape
Brassicas	French Beans	Orchids	Stone Fruit
Broadbeans	Fodder Beet	Ornamentals	Strawberries
Broccoli	Field Peas	Palm Oil	Sugar Beet
Brussel Sprouts	Flax	Parsley	Swede
Buxus	Fuchias	Parsnips	Sweet Corn
Cabbage	Garlic	Pasture	Sweet Potatoe
Calabrese	Geraniums	Peppers	Sunflowers
Cauliflower	Gooseberries	Peas	Tayberries
Cassava	Golf Course	Pears	Tea
Carrots	Grapes Vines Eating	Plums	Top Fruit

Carnations	Grapes Vines Wine	Potatoes	Tomatoes
Cocoa	Grass	Poinsettias	Trees
Coffee	Grazing Land	Primroses	Turnip
Conifers	Herbateous Containers	Prunus	Tulips
Corgette	Hops	Pumkins	Turf
Cherries	Kale	Ranunculus	Wheat
Chillies	Kiwi Fruit	Rape Seed Oil	Woody Ornamentals
Chrysanthemums	Lawn Tennis Courts	Raspberries	Wisteria
Citrus	Leeks	Rice	Winter Wheat
Clementines	Lettuce	Robinia	Winter Beans
Clover	Linseed		

As summarized above, Codacide Oil has been beneficially used on most crops at most growth stages throughout most geographical and climatic zones of the world.

Following (Sections VIII i., ii., and iii.) are summaries of over 100 trials conducted throughout the world on a wide range of herbicides, insecticides and fungicides that show the optimization of efficacy provided by Codacide Oil on a diverse number of crops and targets. The majority of trails summarized are independent and published in respected international journals and publications.

VIII i.) Codacide Extending Herbicide Efficacy - Trials Summary:

Plant Protection Actives	Crop	Target	Synopsis	Country	Reference
2,2-DPA (2,2 dichloropropionic acid)		Serrated tussock (*Nassella trichotoma*)	Codacide Oil (1.5 l/ha) mixed with 2,2-DPA (2.2 kg ha^{-1}) increased control of serrated tussock grass assessed 16 weeks after application with a 8.1 damage score and 40% killed as compared to 2,2-DPA applied alone with a 4.5% damage score and 0% killed.	Australia	Pritchard and Bonilla, 1999
2,4-D Amine		Stinkweed (*Thlaspi arvense L.*)	The addition of Codacide Oil to 2,4-D Amine at full rate and at half rate significantly enhanced control as compared to 2,4-D Amine alone at half rate and full rate.	Canada	Harker, 1997 b.
Asulam + Tribenuron-methyl		Bracken (*Pteridium aquilinum*)	Asulam + Tribenuron-methyl activity was significantly increased by the addition of Codacide Oil and increased the control of bracken as compared to Asulam + Tribenuron-methyl applied alone	UK	Lawrie and West, 1993
Asulam (Asulox)		Bracken (*Pteridium aquilinum*)	The addition of Codacide Oil (2 l/ha) to Asulox (11 l/ha) gave improved control of bracken at 83.7% control in comparison to Asulox applied alone (11 l/ha) which gave 53% bracken control	UK	Elveden, 1997
BA 6-benzyladenine (CyLex - Desiccant Post bloom thinner)		Post bloom thinner on red "Delicous" apple.	Efficacy was improved most by Codacide compared to Tween 20 and Silwett L77 with good thinning rates achieved together with a corresponding increase in fruit size and flesh pressure and significantly so as compared to BA control alone and BA plus Silwett L77 treatments.	Australia	Bound, 2001
Bentazone (Adagio)	Maize	Broadleaved Weeds Barnyard grass (*Echinochloa crus-galli*) Black nightshade (*Solanum nigrum*)	Adagio SG was applied alone at normal rate (1.6 kg/ha) and at reduced rate (1.12 kg/ha) and with Codacide (1.25 l/ha). Codacide improved the efficacy of Adagio at both rates for overall weed control. Improvement in the efficacy of low rate of Adagio was similar to full rate Adagio applied alone. No Phytotoxicity.	France	Biotek Agriculture, 2004 c.
Bentazone + dicamba (Cambio)	Maize	Hedge Bindweed (*Calystegia sepium*) Common lambs quarters (*chenopodium album*)	Cambio was applied alone at normal rate (2.5 kg/ha) and at reduced rate (1.75 kg/ha) and with Codacide (1.25 l/ha). Codacide imporved the efficacy of high rate Cambio in control of *C. Sepium* and improved the efficacy of both rates Cambio for control *C. Album*.	France	Biotek Agriculture, 2004 b.
Benazolin + clopyralid (Benasalox)	Spring Oil Seed Rape	Common lambs quarters (*chenopodium album*), *Lamium sp.*, Common chickweed *(Stellaria media)*	Spring oilseeds. Codacide enhanced the effect of the herbicide against broadleved weeds particularly *C. Album* and *Lamium sp*. Codacide also markedly improved the effect of lower rates of herbicide against *S. media*.	Sweden	Halgren, 1987a
Bromoxynil (Emblem)	Maize	Black nightshade (*Solanum nigrum*)	Emblem was applied alone at normal rate (2.25 kg/ha) and at reduced rate (1.50 kg/ha) and with Codacide (1.25 l/ha). Codacide improved the efficacy of low rate Emblem for the control of *S. nigrum*	France	Biotek Agriculture, 2004 e.
Bromoxynil (Pardner)	Sunflowers	Desiccation	To determine the efficacy of Codacide and Pardner at a range of rates in comparison to other dessication systems. On the basis of dry matter assessment, it was seen that Codacide and Pardner in a mixture of 2 l/ha each, were effective in dessicating sunflowers to the required dry matter and timing and was as effective as the other adjuvant systems but more economical in costs.	Hungary	Hungarian Ministry of Agriculture, 1995
Carbaryl	Cox and Bramley Apples	Thinning in Apples	To test the efficacy of carbaryl at full rate with and without Codacide. With the addition of Codacide the percentage of Cox apples above 65mm increased from 54% to 60%. With the increased addition of Codacide the percentage of Bramley apples above 80mm increased from 46% to 53%.	UK	EMIHR, 1988
Carbaryl (Thinsec 450)	Bramley Apples	Thinning in Apples	To test the efficacy of Thinsec at full rate with Codacide compared to the wetter/spreader Agral, as a thinning agent. With the addition of Codacide the average fruit yield increased from 17.1 to 22.9 t/ha. Average fruit diameter was also increased from 88.7 mm to 90.25	UK	ADAS, 1989

			mm.		
Clodinafop-propargyl + cloquintocet-mexyl (Celio)	Winter wheat	Blackgrass (*Alopecurus myosuroides*)	Trials of Celio at three rates (0.15, 0.3, 0.6 l/ha) alone and with Codacide (2.5 l/ha) showed that Codacide significantly improved efficacy of Celio at all rates for control of *A. Myosuriodes*.	France	Calliope and Stage, 1999
Clodinafop-propargyl + Trifluralin (SL518C)	Winter wheat	Chickweed (*Stellaria media*)	Codacide significantly enhanced chickweed control. No Phytotoxicity.	UK	NRM Efficacy, 1996 b.
Clodinafop-propargyl (Topik) + tribenuron-methyl (Granstar)	Wheat	Italian ryegrass (*Lolium multiflorum)* Wild oats (*Avena ludoviciana)*	To evaluate the effects of Codacide on the control of Italian ryegrass (*Lolium multiflorum)* and wild oats (*Avena ludoviciana)* with a range of rates of Topik (clodinofop-propargyl) in combination with Granstar (tribenuron-methyl). The test showed that Codacide was effective in controlling Italian ryegrass and wild oats in combination with Topik and Granstar	Italy	Bologna University, 2000 c.
Clodinafop-propargyl (Topik)	Winter wheat	Blackgrass (*Alopecurus myosuroides*)	To determine the effects of Codacide on the control of blackgrass with a range of rates of Topik. Codacide significantly enhanced blackgrass control with rates of Topik below 250 ml/ha.	UK	NRM Efficacy, 1996 a.
Clodinafop-propargyl (Topik)	Winter wheat	Blackgrass (*Alopecurus myosuroides*)	Topik plus Codacide improved the control of blackgrass by 10% as compared to Topik plus Actipron mineral oil adjuvant.	UK	Crop Care, 1997 b.
Clopyralid		Lambs-Quarters (*Chenopodium album*)	The addition of Codacide Oil to Clopyralid (0.10 kg/ha ai) significantly increased control of lambs-quaters as compared to Clopyralid applied alone.	Canada	Harker, 1997 c.
Cycloxydim (Laser)	Oil Seed Rape	Control of barley cover crop	Laser with Codacide proved to be more robust than Laser with Actipron, giving significantly better barley control as the rates of laser were reduced	UK	Microcide Ltd, 1993 e.
Cycloxydim (Laser)	Winter Barley	Control of cover crop	Codacide (1.25 l/ha) considerably improved levels of efficacy of Laser (1.25 l/ha) in control.	UK	Oxford Plant Sciences. 1997 c.
Diclofop-methyl + fenoxaprop-P-ethyl (Tigress)	Winter barley	Blackgrass (*Alopecurus myosuroides*)	Clear evidence that Codacide enhanced the effects of Tigress.	UK	Microcide Ltd, 1993 c.
Diclofop-methyl + fenoxaprop-P-ethyl (Tigress)	Winter barley	Blackgrass (*Alopecurus myosuroides*)	The performance of 1.5 l/ha of Tigress was sufficiently enhanced by the addition of 2.5 l/ha Codacide to match that given by the higher rates of 2.0 and 2.5 l/ha of Tigress in the control of black grass.	UK	Levington Agriculture, 1994 a.
Diclofop – methyl (Hoegrass) + Phenoxy Nicotinanilide (Tigrex)	Pot Trials	Ryegrass Mustard Weed	Codacide Oil enhanced the performance of Hoegrass on Ryegrass and Mustard weed. Codacide Oil allowed Hoegrass rates to be reduced from 900 ml/ha to 600 ml/ha with same level of efficacy. Codacide Oil improved the control of Mustard weed with Tigrex.	Australia	Ridge, 1990
Diclofop – methyl (Hoelon)	Barley	Canary Grass (*Phalaris canariensus*)	To compare the efficacy of Hoelon applied at a range of rates, with and without Codacide for awned canary grass control. Codacide significantly improved the control of awned canary grass with Hoelon.	Saudi Arabia	Microcide Ltd, 1994 a.
Diclofop – methyl (Hoelon) + Isoproturon (Arelon) + Triasulfuron (Logran)	Barley	Canary Grass (*Phalaris canariensus*)	Codacide improved the control of canary grass over the rates tested.	Saudi Arabia	Microcide Ltd, 1994 b.
Diquat-dibromide (Reglone Air)	Rape Seed Oil	Dessicant and control of monocot and broadleaved weeds	Codacide Oil gave superior desiccation and yield retention and control of monocot and broadleaved weeds then in comparison to same rates Reglone Air applied alone	Hungary	Lanszki, 2011

Diquat-dibromide (Reglone Air)	Sunflower	Dessicant	The addition of Codacide Oil to Reglone Air significantly reduced drift from aerial application and improved the dessication of Sunflower as compared to Reglone Air applied alone and when used with another adjuvant Mist Control	Hungary	Palmai and Gyulai, 2009 a.
Ethofumesate + phenmedipham (Betanal Tandem)	Sugar beet	Mayweed, Fat Hen	To compare manufacturer's recommended Repeat Low Dose rate of Betanal Tandem on sugar beet with half rate programme with Codacide Oil. Codacide with half rate Betanal Tandem gave similar levels of control when compared to the full recommended rate treatment.	UK	Agrisearch, 1989
Fenoxaprop-ethyl (Cheetah R)	Winter wheat	Blackgrass (*Alopecurus myosuriodes*)	The treatment 1 l/ha of Cheetah R and Codacide (2.5 l/ha) gave similar very high levels of blackgrass control to the manufacturers recommended rates of 2 l/ha and 2.5 l/ha rates applied alone (97-98%), whereas control with 1 l/ha of Cheetah R alone was significantly poorer (84%).	UK	Microcide Ltd, 1993 b.
Fenoxaprop-ethyl (Cheetah R)	Winter wheat	Blackgrass (*Alopecurus myosuriodes*)	Codacide significantly improved blackgrass control with Cheetah R as rates were reduced	UK	Levington Ag, 1994 a.
Fenoxaprop-ethyl (Cheetah S)	Winter wheat	Blackgrass (*Alopecurus myosuriodes*)	To compare the efficacy of Cheetah S applied at a range of rates, with and without Codacide, for blackgrass control. Codacide significantly enhanced control with Cheetah S as rates were reduced.	UK	Microcide Ltd, 1993 b.
Femedifam + Desmedifam + Etofumesate	Sugar Beet	*Polygonum aviculare* *Chenopodium album*	The results of three year trials in Po Valley, Italy showed that Codacide oil improved the control of *P. aviculare* and C. Album with 95% and 99.3% control verses 89.5% and 98.9% control for mineral oil.	Italy	Paci *et al,* 2002
Femedifam + Desmedifam + Etofumesate + Triflusulfuron-metile	Sugar Beet	*Polygonum aviculare* *Chenopodium album*	The results of three year trials in Po Valley, Italy showed that Codacide oil improved the control of *P. aviculare* and C. Album with 96% and 89.1% control verses 92.5% and 88.9% control for mineral oil.	Italy	Paci *et al,* 2002
Flamprop-M-methyl (Mataven)	Wheat	Wild Oats	The addition of Codacide (1 l/ha) to half rate of Mataven (1 l/ha)significantly decreased the wild oat dockage as compared to half rate Mataven applied alone.	Canada	Manning, 1993
Fluazifop-p-butyl (Fusilade)	Oil Seed Rape	Barley control	Codacide improved efficacy of Fusilade and gave significantly better barley control then the adjuvant Agral.	UK	Microcide, 1993
Glyphosate (Roundup)	Maize	Broadleaf weeds (4-6 leaf) Grass Weeds (Tillering)	Codacide used with Roundup at half rate 270 a.i. per ha had very good control of Lolium multiflorum, Echinocloa crus-galli and Portulaca oleracea with results not significantly different with respect to Glyphosate sprayed alone at 540 g a.i. per ha.	Italy	Bologna University, 2001
Glyphosate (Roundup)	Vines Sauvignon Blanc	Cheese weed (*Malva parviflora*) Musky storkbill (*Erodium moshatum*)	Addition of Codacide to Glyphosate treatments improved performance of glyphosate both with regard to initial symptom development on Malva parviflora as well as total weed control.	South Africa	Kelpak, 1997
Glyphosate (Roundup Bi-active)		Common Couch (*Elymus repens*)	Codacide plus Roundup Biactive gave significantly increased control of common couch as compared to roundup Biative applied alone at same rates.	UK	Oxford Plant Sciences, 1997 b.
Glyphosate (Roundup Bi-active)		Barely and Oil Seed Rape cover crops	Codacide significantly increased efficacy in control of barley and oil seed rape of Roundup Bi-active when applied shortly before differing levels of rain intensity as compared to Roundup Bi-active applied alone	UK	Murfitt, 1996
Glyposate		Ryegrass (*Lolium rigidim*)	Codacide gave significantly improved control (at 2% *v/v*) with glyphosate 720g/ha in pot trials on Annual Ryegrass (*Lolium rigidim*) when no rain as well as for 1 hr, 2 hr, and 4 hr after spray application when 30 minutes of 5mm/per hr simulated rainfall was applied.	Australia	Combellack *et al*, 2001
Glyphosate (Roundup)	Set Aside Land	Scentless Mayweed, Creeping Thistle, Volunteer Wheat	Applying Roundup with Codacide gave substantially improved levels of control of volunteer wheat, scentless mayweed and creeping thistle.	UK	Microcide Ltd, 1993 d.

Glyphosate	Barley	Barley cover crop	The addition of Codacide Oil to Glyphosate at full rate and at half rate significantly enhanced control as compared to Glyphosate alone at half rate and full rate.	Canada	Lacombe Research, 1991 b.
Glyphosate (Roundup CT)	Barley	Barley cover crop	Codacide Oil significantly increased the efficacy of Roundup CT on Barley cover crop control	Australia	Lott, 1990
Glyphosate	Clementines	Grass and dicotyledon weeds	To compare the effectiveness of glyphosate with Codacide in the control of grass and dicotyledon weeds. At 13 days after application Codacide showed improved efficacy as compared to glyphosate alone. At 31 days after application all weeds were controlled with the exception of *Malva,* with no significant differences between the treatments	Spain	Trialcamp S.A.L, 1996 a.
Glyphosate (Roundup)	Set Aside Land	Couch grass, Wild Oats, Willow Herb	When Codacide was used with glyphosate at the 2 l/ha rate, there was 100% control of couch and wild oats (compared to 89% and 96% without Codacide) and 70% (compared to 57% without Codacide) of willow herb. At the rate 1 l/ha rate Codacide gave 80%, 93% and 50% control respectively.	UK	Levington Ag., 1994 b.
Glyphosate (Glyfos)	Rape Seed Oil	Dessicant and control of monocot and broadleaved weeds	Codacide Oil gave superior desiccation and yield retention and control of monocot and broadleaved weeds then in comparison to same rates Glyphos applied alone	Hungary	Lanszki, 2011
Glyphosate	Radishes	Lolium rigidum, Sisymbrium officinale, *Avena fatua.*	Codacide increased control of all weed species when mixed with glyphosate as compared to glyphosate used alone	UK	Wells, 1989
Glyphosate trimesium (Medallon)	Sunflower	Dessicant	To determine the effeciacy of Medallon and Codacide in comparison to other dessicant systems. Codacide consistently reduced dry matter over other treatments.	Hungary	Zeneca, 1996
Imazamethabenz + Alkyphenoxypoly – ethyl phosphate (Merge)		Wild Oats (*Avena fatua*)	Codacide significantly enhanced the activity of Imazamethabenz in the control of wild oats over standard applications of Imazamethabenz alone and with other adjuvants	Canada	Lacombe Research, 1991 a.
Isopropylideneamino (post emergence broad spectrum grass herbicide)		Wild oat (*Avena fatua*)	In replicated trails the addition of Codacide Oil to the postemergence broadspectrum grass herbicide (isopropylideneamino) significantly increased herbicide activity in the control of wild oats at wild oat fresh weight of 5.2 g pot^{-1} as compared to RO-17-3664 applied with no adjuvant at 9.3 g pot^{-1}.	Canada	McMullan and Czerkawski, 1991
Isoproturob + diflufenican (Panther)	Winter barley	Chickweed, Field Pansy, Mayweed, Field Speedwell	To compare the efficacy of Panther applied at a range of rates, with and without Codacide, for broadleaved weed control. Codacide significantly improved control with Panther at a arnge of rates of application.	UK	Microcide Ltd, 1994
Mecoprop+Bromoxynil+Ioxynil (Axall)	Wheat	Broad Leaved Weeds	Codacide enhanced weed control, with 1.5 l/ha of Axall applied with Codacide giving similar levels of control to 3.0 l/ha of Axall applied alone.	Saudi Arabia	Micrcoide Ltd 1994 c.
Mekoprop-P (Duplosan KV)	Winter Wheat	Dicotyledons (4-6 leaves) *Galium aparine* *Viola arvensis* *Veronica hederifolia*	The addition of Codacide increased the efficacy of the herbicide Duplosan especially in the control of *Galium aparine, Viola arvensis, and Veronica hederifolia in winter wheat as compared to Duplosan applied alone*	Hungary	Koroknai and Miklos, 1995
Mekoprop-P (Duplosan KV)	Spring Barley	Dicotyledons (4-6 leaves) *Galium aparine* *Viola arvensis* *Veronica hederifolia*	Codacide oil (2.5 l/ha) significantly improved the efficacy of Duplosan in control of dicotyledon weeds in spring barley at three duplosan rates of 0.9, 1.2, 1.5 kg/ha as compared to duplosan applied alone.	Hungary	Palmai and Nagy, 1995
Mesotrione (Callisto)	Maize	Grass and Broadleaved weeds	To compare the effectiveness of Mesotrion (with BIW) at varying rates with Mesotrion at reduced rates (with the addition of a range of adjuvants) on a crop of maize to control a number of grass and broadleaved weeds. The addition of adjuvants to the reduced rates of Mesotrion enhanced the effectiveness of Mesotrion. In particular Codacide significantly improved the effectiveness of Mesotrion over other adjuvants.	Hungary	Syngenta, 2000

Mesotrione (Callisto) + Rimsulfuron (Titus)	Maize	*Capsella bursa pastoris, Amaranthus retroflexus, Solanum nigrum, Abutilon theophrasti, Chenopodium album, Echinochloa crus galli*	In the control of all weeds, the mixture Titus + Callisto added to Codacide showed higher efficacy value, as compared to mixture Titus + Callisto applied alone. Further in 13 treatments assessing 9 herbicides, the mixture Wonder+Merlin+Codacide showed the best broadleaved weed control.	Italy	Agricola, 2004
Metamitron (Goltix) + Ethofumesate (Nortron)	Sugar beet	Mayweed, Fat Hen	Against all species tested, the half rate herbicide mixtures with Codacide had achieved at least as good control as the full rate herbicides applied alone and in most cases had improved control by a considerable margin.	UK	Agrisearch, 1989
Metamitron (Goltix) + Ethofumesate (Tramat) + Phenmedipham/desmediph am (Betanal AM)	Sugar beet	Broad leaved weeds	Three years of trials evaluates the effect of adding adjuvants at two timings to post emergent herbicides to increase the efficacy of broadleaved weed control. After three years of testing Codacide significantly improved the efficacy of broadleaved weed control over a range of adjuvants	Spain	AIMCRA, 1997
Nicosulfuron (Milagro 40 SC)	Maize	*Setaria verticillata*, *Atriplex patula*, *Lolium multiflorum*, *Matricaria chamomilla*, *Echinochloa crus-galli Daucus carota*, *Amaranthus retroflexus Chenopodium album*, *Polygonum persicaria*, *Solanum nigrum*, *Setaria pumila*	In ten replicated trails, Milagro at reduced rate of 1.125 l/ha with Codacide at 1.25 l/ha achieved comparable efficacy of all weed species and improved efficacy for hard to wet species as found with full rate 1.5 l/ha Milagro alone	France	Solevi, 2001
Nicosulfuron		Summer grass (*Digitaria sanguinalis*), smooth witchgrass (*Panicum dichotomiflorum*)	Codacide (1 l/ha) applied with Nicosulfuron improved the control of smooth witchgrass (97 % control) compared to Nicosulfuron applied alone (65% control).	New Zealand	James and Rahman, 1990
Oxasulfuron (Dynam)	Soya	Broadleaved weeds	To evaluate the effects of Codacide in combination with Dynam at 2 rates on the control of a range of broadleaved weeds in a crop of soya. Codacide enhanced the efficacy of Dynam at the higher rate and was slightly more effective than the other treatments.	Italy	Bologna University, 2000 e.
Phenmedipham	Field Beans	Wild Oats	Codacide Oil significantly increased the control of wild Oats when mixed with Phenmedipham at both 0.50 and 2.00% as compared to Phenmedipham applied alone	UK	Western, *et al*, 1998
Phenmedipham (Kemifam S) + Metamitron (Goltix) + Clopyralid (Lontrel)	Sugar Beet	Broadleaved Weeds	To demonstrate the efficacy of adjuvants at two timings in tank mix combination in the control of broadleaved weeds. Averaged over two sites and two timings and weed species, Codacide was the most effective adjuvant in the control of broadleaved weeds.	Spain	AIMCRA, 1995
Potassium thiosulfate-KTS (Dessicant blossom thinner)		Flowering spurs of the Gala Apple	Codacide shown to increase the desiccating effect of KTS.	Australia	Bound *et al* 2006
Primisulfuron		Summer grass (*Digitaria sanguinalis*), smooth witchgrass (*Panicum dichotomiflorum*)	Codacide (1 l/ha) applied with Primisulfuron improved the control of smooth witchgrass (95% control) and Summer Grass (57% control) compared to Primisulfuron applied alone (78% and 48% control).	New Zealand	James and Rahman, 1990
Pyraflufen-ethyl (OS-159)	Cotton	Desiccant defoliant	To evaluate the effectiveness of OS-159 with Codacide at different rates in the defoliation and desiccation of cotton. Codacide at all treatment rates over 2 sites effectively defoliated and desiccated cotton, with the 1.0 l/ha rate being slightly more effective than the 0.5 and 2.5 litre rate. Codacide enhanced the application of OS-159 and had excellent efficacy even at the lowest rate of OS-159. A very fast action in the defoliation and desiccation of cotton was noticed with the addition of Codacide.	Spain	Agrodan, 2000 a

Pyroxysulam (Pallas 45OD)	Wheat	Dicot weeds and grasses	Good control of dicot weeds and grasses was achieved	Kenya	Lachlan, 2009
Quizalofop-ethyl (Pilot)	Sugar beet	Volunteer barley control	To compare the efficacy of Pilot at a range of rates, with and without Codacide, for the control of volunteer barley. Codacide significantly improved the control of Pilot at all rates tested .	UK	Croda, 1994 a.
Rimsulfuron (Titus)	Tomatoes	Broadleaved weeds	To evaluate the effects of Codacide in combination with Titus on the control of broadleaved weeds in a crop of tomatoes. Codacide was effective in controlling broadleaved weeds in combination with Titus.	Italy	Bologna University, 2000 g.
Rimsulfuron		Smooth witchgrass (*Panicum dichotomiflorum)* Summer grass (*Digitaria sanguinalis).*	Codacide (1 l/ha) applied with Rimsulfuron improved the control of smooth witchgrass (98% control) and Summer Grass (95% control) compared to Rimsulfuron applied alone (60% and 50% control).	New Zealand	James and Rahman, 1990
Rimsulfuron (Titus)	Maize	Broadleaf weeds (4-6 leaf) Grass Weeds (Tillering)	Codacide when mixed with Titus allowed a more prompt effect in weed control than compared to mixture of Titus plus the adjuvant Trend. Codacide was very effective in co-ordinating Titus in controlling *Amaranthus retroflexus* and *Portulaca oleracea*.	Italy	Bologna University, 2001
Rimsulfuron (Titus) + dicamba (Mondak)	Maize	Broadleaved weeds	To evaluate the effects of Codacide in combination with Titus and Mondak on the control of a range of broadleaved weeds in a crop of maize. Codacide enhanced the efficacy of Titus on the control of broadleaved weeds and was more effective than the other treatments.	Italy	Bologna University, 2000 d.
Rimsulfuron (Titus) + dicamba (Mondak)	Maize	Barnyard grass (*Echinochloa crus-galli)* and Black nightshade (*Solanum nigrum)*	To evaluate the effects of Codacide in combination with Titus and Mondak on the control of Barnyard grass (*Echinochloa crus-galli)* and Black nightshade (*Solanum nigrum)* in a crop of maize. Codacide enhanced the efficacy of Titus on the control of Barnyard grass and Black nightshade was slightly more effective than the other treatments applied with the adjuvant Trend.	Italy	Bologna University, 2000 d.
Rimsulfuron Rimsulfuron+Nicosulfuron	Wheat Maize	*Echinochloa crus-galli*, *Polygonum lapathifolium, Follopia convolvulus*, *Chenopodium album, Solanum nigrum, Amaranthus retroflexus*.	Codacide with rimsulfuron and with the mixture rimsulfuron+nicosulfuron gave the best results particularly for *E. Crus-galli* as compared to adjuvants Etravon, Adigor, Biopower, Dash HC and Breakthrough on wheat and maize application.	Italy	Rapparini *et al*, 2009.
Rimsulfuron + thifensulfuron-methyle (Basis)	Maize	*Panicum miliaceum*, *Echinochloa crus-galli*, *Chenopodium album*, *Solanum nigrum*, *Polygonum persicaria*.	Basis was applied alone at normal rate (0.025 kg/ha) and at reduced rate (0.015 kg/ha) and with Codacide (1.25 l/ha). Codacide improved the efficacy of Basis for the control of all weed species.	France	Biotek Agriculture, 2004 d.
Soyal phospholids (Chlormequat) + Trinexapac-ethyl (Moddus)	Winter wheat	Crop height and lodging control	Codacide reduced crop lodging percentage and significantly reduced crop height over standard chlrmequat and Moddus treatments	Ireland	University College Dublin, 1996
Sulcotrione (Mikado 300 SC)	Maize	*Setaria verticillata*, *Atriplex patula*, *Lolium multiflorum*, *Matricaria chamomilla, Echinochloa crus-galli*, *Daucus carota*, *Amaranthus retroflexus*, *Chenopodium album*, *Polygonum persicaria*, *Solanum nigrum*, *Setaria pumila*	In ten replicated trails, Mikado at reduced rate of 1.125 l/ha with Codacide at 1.25 l/ha achieved comparable efficacy of all weed species and improved efficacy for hard to wet species as found with full rate 1.5 l/ha Mikado alone	France	Solevi, 2001
Sethoxydim (Expand)	Spring Oil Seed Rape	Couchgrass (*Elymus repens*)	Codacide enhanced the activity of herbicide on assessment one month after spraying, with associated increases in crop yield.	Sweden	Halgren, 1987b
Sethoxydim	Barley	Barley cover crop	The addition of Codacide Oil to Sethoxydim at full rate and at half rate significantly	Canada	Harker, 1997 a.

			enhanced control as compared to Sethoxydim alone at half rate and full rate.		
Sethoxydim		Wild oat (*Avena fatua*)	Greenhouse experiments revealed that Codacide provided better control of wild oats then herbicide alone or plus the adjuvant Assist.		McMullan and Czerkawski, 1991
Sethoxydim (Checkmate)	Sugar beet	Volunteer barley control	To compare the efficacy of Checkmate at a range of rates, with and without Codacide for the control of volunteer barley. Codacide significantly improved the control of Checkmate at a third of the recommended dose.	UK	Croda, 1994 b.
Thifensulfuron		White Mustard (*Sinapis alba*)	The addition of Codacide Oil to Thifensulfuron significantly increased its potency as compared to Thifensulfuron applied alone	Denmark	Kudsk, 1992
Tribenuron-methyl (Safari)	Sugar Beet	Broadleaved weeds	To evaluate the effects of Codacide in combination with Safari and a range of tank mixtures on the control of broadleaved weeds in a crop of sugar beet. Codacide was effective in controlling broadleaved weeds in combination with Safari and tank mixtures and more effective than other treatments.	Italy	Bologna University, 2000 f.
Tribenuron-methyl		Bracken (*Pteridium aquilinum*) Heather (*Calluna vulgaris*)	Codacide with Tribenuron-methyl improved control of bracken and heather as compared to Tribenuron-methyl applied alone.	UK	West and Lawrie, 1993
Tribenuron-methyl		Wild mustard (*Sinapis arvensis*), scentless mayweed (*Tripleurospermum inodorum*), common poppy (*Papaver rhoeas*), common lambsquarters (*chenopodium album*)	The activity of Tribenuron-methyl was significantly enhanced by the addition of Codacide Oil on all weed species. The ED50 doses were reduced by a factor of 2-20 when Codacide Oil was included in the spray solution. The inclusion of Codacide Oil enhanced the activity of Tribenuron-methyl on the weeds significantly more (*P*=0.05) at the eight-true-leaf stage, compared to the four-true-leaf stage.	Italy	Pannacci *et al*, 2010
Triclopyr		Purple flowered rhododendron (*Rhododendron ponticum*)	Found that the greatest control for the lowest triclopyr rate application was achieved by Codacide Oil, with only 15% regrowth 15 Months After Treatment when compared to the control level achieved by non-adjuvant added triclopyr application as well as in comparison to three other adjuvants	Australia	Lawrie and Clay, 1993
Tifesulfuron – methyl (Harmony) + Imazamox (Tropical)	Soya Bean	Broad Leaved Weeds Barnyard grass (*Echinochloa crus-galli*) Flower of the Hour (*Hibiscus trionum*).	Codacide gave an increased control on barnyard grass in respect to same rate treatments of harmony and Tropical applied without Codacide. At last assessment (28 DAT) Codacide showed complete control of broad leaved weeds and conferred best herbicide effect vs. *Hibiscus trionum.*	Italy	Agri2000, 2004
Trifluralin + Clodinafop-propargyl + cloquintocet-mexyl	Winter wheat	Blackgrass, Ivy leaved Speedwell, Chickweed, Field pansy, Wild oats	Codacide significantly enhanced chickweed control regardless of rate of application or timing and was due to a reduction in volatisation. In addition low blackgrass populations were completely controlled as was light infestation of spring germinating wild oats.	UK	NRM Efficacy, 1996 a.
Trifluralin (Treflan)	Winter barley	Small Nettle, Chickweed, Field Speedwell	Good evidence to show that Codacide had enhanced broad leaved weed control with Treflan	UK	NRM Efficacy, 1993
Trifluralin (Treflan)	Winter barley	Field Pansy, Ivy Leaved Speedwell, Chickweed, Scentless Mayweedl	Combined counts of all weeds showed that Codacide significantly enhanced control.	UK	NRM Efficacy, 1995
Triflusulfuron – methyl (Debut) + Phenmedipham (Betanal E) + Lenacil (Venzar Flo)	Sugar Beet	Broadleaved weeds	Codacide improved control of weeds from 40% water alone to between 92 and 99% as compared to 79% for Actipron.	UK	Crop Care, 1997 a.

VIII. ii.) Codacide Extending Insecticide Efficacy - Trials Summary:

Plant Protection Actives	Crop	Target	Synopsis	Country	Reference
Abamectin (Vertimec)	Apples	Two spotted Mite (*Tetranychus urticae*) European Red Mite (*Panonychus ulmi*)	Vertimec plus Codacide at both rates of 2.5 and 5l/ha provided very good control of the two spotted mite and European red mite in contrast to Vertmec applied alone.	Australia	Collet *et al*, 2002.
Acephate	Cucumber Tomato	Melon Aphid Tomato Fruitworm	Codacide Oil when mixed with Acephate improved the control of Melon Aphid on cucumber (18 Mean Insect Numbers per plant MIN) compared to Acephate applied alone (23 MIN) and significantly improved control of Tomato Fruitworm on tomato (1 MIN verses 2 MIN).	New Zealand	Gaskin *et al*, 2002
Achrinathrin (Rufast)	Strawberry	Western flower thrips larvae and adults (*Frankliniella occidentalis*)	Codacide plus Rufast provided enhanced efficacy in the control of larvae and adult thrips on strawberry in comparison to Rufast applied alone	Spain	Agrodan, 2005
Benfuracarb (Oncol)	Apple Orchards	aphids *Aphis pomi* and *Dysaphis plataginea*	To compare the effectiveness of Oncol formulations and Oncol + Codacide in the control of aphids *Aphis pomi* and *Dysaphis plataginea* in apple orchards. Trial 1 showed that 3 DAA a significantly higher efficacy (98.8%) was achieved with the combined treatment Oncol + Codacide than any other treatment.	Spain	Agrodan, 2000 b.
Bendiocarb + Deltamethrin	Laboratory	*Locusta migratoria*	Codacide improved efficacy of topically applied bendiocarb and Deltamethrin in the control of *Locusta migratoria*.The increase was greatest with Deltamethrin against adult locust and significant at 36 and 48 hrs after treatment.	Bangladesh	Hossain *et al,* 1998
Carbomate (Larvin) + Dipel (*Bacillus thuringiensis*) + Chlorofos	Siokra Cotton	Heliothis Aphids	In field trails Codacide Oil (2 l/ha) gave a consistent advantage in the control of heliothis and aphids	Australia	Wilson, 1991
Diazinon (Basudin 600 EC)	Amenity Grass	Moth caterpillars (*Heliothis armiger*)	Codacide achieved same control of caterpillars at half rate (0.75 l/ha) Basudin as compared to full rate.	Oman	Microcide and GDC, 1992
Dichlorvos (Nogos 50 EC)	Date Palms	Dubus Bug (*Dubus omatesus binotatus*)	To test the effectiveness of Nogos when applied aerially through Micronair CDA heads at half rate with Codacide when compared with the manufacturers recommended rate of Nogos applied alone (3.7 l/ha). With half rate Nogos and Codacide no loss of efficacy was found. Both treatments gave virtually complete control (over 99%)	Oman	Ministry of Agriculture Oman, 1992
Dimethoate	Sugar Beet	Aphids (*Aphis fabae*)	Codacide plus dimethoate provided enhanced efficacy in the control of aphids on sugar beet in comparison to dimethoate applied alone	Spain	Agrodan, 2005
Dimethoate	Broccoli	Cabbage Aphid (*Brevicoryne brassicae*)	Codacide plus dimethoate provided enhanced efficacy in the control of cabbage aphids on broccoli in comparison to dimethoate applied alone	Spain	Agrodan, 2005
Dimethoate	Brussel Sprouts	Aphids Caterpillars	Codacide applied with full rate and half rate dimethoate improved efficacy in aphid and caterpillar control with half rate Codacide and dimethoate control being similar to full rate dimethoate alone.	UK	HRI Stockbridge, 1995 a.
DSM	Brussel Sprouts	Aphids Caterpillars	Codacide applied with full rate and half rate DSM improved efficacy in aphid and caterpillar control with half rate Codacide and DSM control being similar to full rate DSM	UK	HRI Stockbridge, 1995 b.

			alone.		
Fenbutatin Oxide (Torque)	Pepper *Capsicum annuum*	Two-spotted mite (*Tetranychus urticae*)	Addition of Codacide Oil (2.5 l/ha) to Torque at rates 0.15 , 0.3, 0.6 kg/ha improved efficacy against Two-spotted mite by 23.9%, 20.4% and 15% respectively as compared to Torque applied alone.	Hungary	Palmai and Szeoke, 1995
Fenitrothion		Juvenile Locusts (*Orthoptera. Senegalensis*)	The efficacy of reduced rates of insecticide Fenitrothion with Codacide on juvenile locusts was evaluated and showed that even with less than half rate Fenithrothion with Codacide gave 100% control of juvenile locusts within 45 minutes.	Mali	Stromme Foundation, 1987
Indoxacarb (Steward)	Tomato	*Tuta absoluta*	The addition of Codacide Oil to Steward improved effective control of *Tuta absoluta* to over 90% 15 days after treatment compared to under 80% for Steward applied alone.	Spain	Plasencia *et al*, 2008
Indoxacarb (Steward)	Tomato	*Tuta absoluta*	A total of 13 trials were conducted from 2007 to 2010 in Spain to evaluate the use and performance of Codacide Oil applied in tank mix with Steward in the control of *Tuta absoluta* on Tomatoes. These trials showed that the addition of Codacide Oil (2.5 l/ha) consistently and significantly increased the control of *Tuta absoluta* in contrast to Steard applied alone (125gfp/ha). Improved performance is considered highly beneficial to help growers achieve sutainable and effective control of this difficult pest.	Spain	DuPont, 2011
*Lecanicillum longisporum (*entomopathogenic fungus – Vertalac)	Blackcurrant	Gall Mite	In field trials the efficacy of Vertalec (entomopathogenic fungus *Lecanicillum longisporum*) with and without Codacide Oil was evaluated for the control of gall mite on Blackcurrants. After four replicated treatments, Vertalec alone had no, or at best, only modest affects at 194 mites per trap compared to control of 313. Codacide Oil plus Vertalec greatly increased efficacy to only 46 mites per trap.	UK	Defra, 2006 b.
Malathion (Acuafin)	Citrus	Red Scale (*Aoinidiella aurantii*)	Codacide plus Acuafin provided enhanced efficacy in the control of red scale on citrus in comparison to Acuafin applied alone	Spain	Agrodan, 2005
Malathion (Acuafin)	Strawberry	Thrips larvae and adults (*Thrips tabaci*)	Codacide plus Acuafin provided significant enhanced efficacy in the control of thrips on strawberry in comparison to Acuafin applied alone	Spain	Agrodan, 2005
Malathion (Acuafin)	Olive Tree	Fruit Fly (Bactrocera olea)	Codacide plus Acuafin provided increased efficacy in the control of fruit fly on olives for larvae and adults in comparison to Acuafin applied alone	Spain	Agrodan, 2005
Malathion (Acuafin)	Stone Fruits	Leafhoppers (*Empoasca*)	Codacide plus Acuafin provided enhanced efficacy in the control of leafhoppers on stone fruits in comparison to Acuafin applied alone	Spain	Agrodan, 2005
Malathion (Acuafin)	Stone Fruits	Thrips larvae and adults (*Thrips tabaci*)	Codacide plus Acuafin provided enhanced efficacy in the control of larvae and adult thrips on stone fruits in comparison to Acuafin applied alone	Spain	Agrodan, 2005
Malathion (Acuafin)	Cereals	Aphids (*Sitobium avenae*)	Codacide plus Acuafin provided efficacy in the control of aphids on cereals.	Spain	Agrodan, 2005
Malathion (Acuafin)	Cotton	Thrips (*Thrips tabaci*)	Codacide plus Acuafin provided enhanced efficacy in the control of thrips on cotton in comparison to Acuafin applied alone	Spain	Agrodan, 2005
Malathion (Acuafin)	Lucerne	Aphids (*Aphis fabae*)	Codacide plus Acuafin provided enhanced efficacy in the control of aphids on Lucerne in comparison to Acuafin applied alone	Spain	Agrodan, 2005
Metarhizium flavoride (Mycoinsecticide)		Dessert Locust (*Schistocerca gregaria)*	To compare the effect and application method of the efficacy of aerial and submerged conidia of *Metarhizium flavoride* for locust and grasshopper control. The mean AST	UK	CABI, 1995

		Grasshopper	(average survival time days) for the Codacide knapsack application was significantly lower than the other treatments.		
Metarhizium anisopliae (Mycoinsecticide)		*Boophilus microplus* (Ticks)	Addition of 2% Codacide Oil achieved 100% germination after 48hrs for conidia of *Metarhizium anisopliae*. Average Survival Time (AST) for *Boophilus microplus* (ticks) was reduced from 8.4 days for *M.anisopliae* and water alone to 7.4 days for *M.anisopliae* and 2% Codacide Oil. Codacide Oil also tended towards a lower AST as compared to 2% liquid paraffin EAO or 2% Cropspray adjuvants.	Australia	Polar *et al.,* 2005
Metarhizium anisopliae (Mycoinsecticide)		Meal Worm *Tenebrio molitor* larvae	To compare the effectiveness of emulsifiable oil fungal formulations to a standard water plus Tween 80 and Peanut oil at different doses of *Metarhizium anisopliae* conidia and to observe if the emulsifiable oil content can enhance the performance of fungal conidia on *Tenebrio molitor* larvae. The relative mean potency for LD50 and LD95 of each formulation shows that Codacide was 1.3 times more effective than Peanut oil, 2.9 times more effective than 10% Natur'l oil and 17 times more effective than water + 0.05% Tween 80.	UK	Alves *et al*, 1998
Metarhizium anisopliae (Mycoinsecticide)		*Boophilus microplus* (Cattle Tick)	Pen studies on the control of cattle tick with *Metarhizium anisopliae* formulated with 10% Codacide Oil assisted to rapidly cause 100% mortality in unengorged ticks and cause a significant reduction in egg production of engorged ticks that were removed from cattle and cultured in the laboratory	Australia	Leemon *et al,* 2008
Metarhizium anisopliae (Mycoinsecticide)		*Schistocerca gregaria* (Dessert Locust).	Showed that Codacide Oil significantly assisted secondary pick up of *M. anisopliae conidia* by the dessert locust (*Schistocerca gregaria*).	Brazil	Alves *et al,* 2000
Metarhizium anisopliae (Mycoinsecticide)		Tropical Bont Tick	The study found that Codacide Oil enhanced the efficacy of *Metarhizium anisopliae* and increased mortality of the Tropical Bont Tick by reducing the humidity requirements for spore germination.	Caribean	FAO and IFAD, 2003
Metarhizium flovoviride (Mycoinsecticide)		Locust Grasshoppper	For submerged conidia of *Metarhizium flovoviride* for locust and grasshopper control, it was found that the mean survival time of infected locusts was significantly shorter for treatments using a knapsack sprayer containing submerged conidia in water plus 10 ml litre-' 'Codacide' (seven days), than treatments with aerial conidia in oil using ULV techniques (8.9 days) or submerged conidia in modified (water plus adjuvants) ULV (MULV) (nine days) or in water-based (VLV) applications (9.3 days). Codacide Oil also provided greater protection of the conidia from environmental stresses.		Jenkins and Thomas, 1996
Methoxyfenozide (Runner 240 SC)l	Carnations	Caterpillars	Addition of Codacide Oil to Runnerr improved control of caterpillars on carnations and was as affective as Silwet Gold.	Kenya	Oserian, 2011
Omethoate (Folimat)	Cucumbers	Leaf miner (*Liriomyza trifolii*)	To test the efficacy of the insecticide Folimat with and without Codacide for the control of leaf miner on cucumbers. A range of rates of Folimat were applied with Codacide to greenhouse grown cucumbers, and compared to a standard rate of 1 l/ha applied alone. Four days after application, rates of Folimat ranging from 0.1 to 1 l/ha applied with Codacide gave from 37-77% control of leaf miner while 1 l/ha of Folimat applied alone gave only 19% control.	Middle East	Microcide Ltd, 1992
Omethoate	Rye Grass	Fruit Fly	To assess the efficacy of the insecticide Omethoate, with and without Codacide for the control of Fruit Fly on newly sown Italian rye grass (at 4 leaves growth stage) with a water volume of 300 l/ha. The efficacy of Omethoate at half dose was improved markedly by	UK	ARC, 1985

			the addition of Codacide Oil.		
Isofenphos (Oftanol)	Onions	Thrips	To compare the effectiveness of Oftanol with adjuvants Codacide and Nu-Film in the control of thrips in a crop of onions. All treatments suppressed the number of thrips compared to the control with no significant differences between the treatments.	Spain	Trialcamp S.A.L Spain, 1996 b.
Permethrin (Reslin Super)		Mosquitoes	Codacide improved efficacy of Reslin Super from 50-60% to 71-80% control of Mosquitoes through aerial spray application	Hungary	Ministry Health Hungary, 1995
Propargite (Omite)	Carnations	Two Spotted Mite (*Tetranychus urticae*)	At half rate Omite with Codacide provided 45% mite reduction one week after application as compared to full rate Omite alone at 39%.	Kenya	Sulmac Brooke Bond, 1996
Spinetram (Radiant 120 SC)	French Beans	Caterpillar (*Heliothis armigera*)	In replicated trials over three seasons and using ANOVA data analysis it was found that Codacide (2 l/ha) with Radiant (120 ml/ha) significantly improved control of caterpillar on French Beans (36.08 no. pods damaged) as compared to Radiant (120 ml/ha) applied alone (51.5 no. pods damaged). Also Radiant and Codacide treatment improved yield at 18.03 t/ha compared to radiant alone treatment of 16.06 t/ha.	Kenya	JAL, 2011 a.
Spinetram (Radiant 120 SC)	Tomatoes	Caterpillar (*Heliothis armigera*)	In replicated trials over three seasons and using ANOVA data analysis it was found that Codacide (125 m l/ha) with Radiant (120 ml/ha) significantly improved control of caterpillar on Tomatoes (41.00 no. pods damaged) as compared to Radiant (120 ml/ha) applied alone (66.66 no. pods damaged).	Kenya	JAL, 2011 b.
Spinosad (Tracer 480 SL)	Carnations	Thrips	Addition of Codacide Oil to Tracer improved control of thrips on carnations and was as affective as Silwet Gold.	Kenya	Oserian, 2011
*Verticillium lecanni- (*Mycotal- Mycoinsecticide)	Poinsettias	Whiteflies (*Trialeurodes vaporariorum & Bermisia tabaci)*	To evaluate the effects of Codacide applied alone and in combination with Mycotal (*Verticilium lecanni)* for the control of whiteflies (*Trialeurodes vaporariorum & Bermisia tabaci)* on poinsettias. Codacide significantly enhanced the activity of Mycotal in reducing whitefly numbers.	Italy	Bologna University, 2000 b.
Verticillium lecanii (Entomopathogenic fungus)	Cucumber	Frankliniella occidentalis, Tetranychus urticae, Aphis gossypii, Myzus persicae (Aphids, Thrips)	The addition of Codacide Oil to V. Lecanii significantly increased its efficacy in control of aphids and thrips.	UK	Helyer, 1993
Verticillium lecanii (Entomopathogenic fungus)		Peach Potato Aphid (*Myzus persicae)*	When comparing the potential of 14 adjuvants in promoting the virulence of the entomopathogenic fungus *Verticillium lecanii* in the control of the peach potato aphid *Myzus persicae* found that Codacide Oil had a statistically significant affect on improving the level of infection relative to the standard preparation of *V. Levanni* alone.	UK	De Courcy Williams *et al,* 2000
Verticillium lecanii (Entomopathogenic fungus)	Tomatoes	Tobacco Whitefly (*Bemisia tabaci*)	Codacide Oil significantly raised the *Bemisia tabaci* mortality (29.5%) by *Verticillium lecanii* as compared to V. Lecanii applied alone	UK	Defra, 2003.

VIII. iii.) Codacide Oil Extends Fungicide Efficacy - Trials Summary:

Plant Protection Actives	Crop	Target	Synopsis	Country	Reference
Copper Oxychloride (Cupravit)	Grape	Downy Mildew (*Plasmopara viticola*)	Codacide and copper (higher rate) had less leaf infectivity than all other treatments and less bunch infectivity than other treatments except dithane.	Italy	Bologna University, 2000
Copper Hydroxide	Cocoa	Cocoa Frosty Pod (*Moniliophthora roreri*)	The addition of Codacide Oil significantly improved the performance of copper hydroxide in control of frosty pod on cocoa	Costa Rica	Hidalgo*, et al* 2003
Dimethomorph + Mancozeb (Acrobat MZ)	Onions	Downy Mildew	In comparing oil based adjuvants (Codacide, Synertrol, DC Tron) and non ionic adjuvants (Top Wet, Tween 80, NuFilm) with Acrobat alone and in combination with Adjuvants it was found that Codacide in pre-infection treatments significantly reduced disease severity and completely suppressed sporulation. Codacide with Acrobat maintained the same level of inhibitory effect on disease progress when applied post-infection unlike Acrobat applied alone or in combination with non ionic adjuvants Top Wet, Tween 80, and Nufilm.	Australia	Mac Manus *et al*, 2002
Epoxiconazole (Opus)	Winter wheat	Leaf blotch (*Septoria tritici*)	To determine the efficacy of Opus applied at a range of rates, with and without Codacide for *Septoria tritici* control. Codacide significantly reduced *Septoria tritici* infection on leaf 3, 13 days after spraying and leaf 2, 29 days after sparying when analysed over all doses of Opus	UK	Scottish Agricultural College, 1995
Flutriafol (Pointer)	Winter wheat	Leaf blotch (*Septoria tritici*)	To compare the efficacy of Pointer applied at a range of rates, with and without Codacide for *Septoria tritici* control. Single sprays of a range of rates were applied with and without Codacide to winter wheat at GS Z 39 and showed Codacide significantly increased efficacy of Pointer in control of *Septoria triciti* and improved grain yield and hectolitre weight.	UK	ADAS Rosemaund, 1993
Flutriafol (Impact)	Garlic	Rust (*Puccinia allii*)	Codacide gave better control of rust in Garlic leaves (as percentage of area damaged) and in reducing number of plants affected as compared to Impact applied alone	Spain	Agrodan, 2005
Fosetyl AL + Mancozeb (Mikal)	Potato	*Phytophtora infestans*	Codacide significantly increased Mikal control of *Phytophtora infestans* at all rates of 1, 2,3,4 kg/ha applied with greater improvement in efficacy found at lower Mikal rates.	Hungary	Palmai and Szekely, 1995
Iprodione (Rovral)	Cheery Trees	Cherry leaf scorch (*Gnomonia erythrostoma*)	Codacide significantly increased efficacy of Rovral in control (95% vs 70%) of leaves affected and (97% vs. 45%) fruits affected as compared to Rovral applied alone	Spain	Agrodan, 2005
Iprodione (Rovral)	Cheery Trees	Cherry leaf spot (*Blumeriella jaapii*)	Codacide extended improved efficacy in the control of leaf spot on leaves and in fruits as compared to Rovral applied alone	Spain	Agrodan, 2005
Mancozed (Dithane M45)	Potatoes	Early Blight	In replicated trials over three seasons, the addition of Codacide (2 l/ha) to Dithane (2 kg/ha) significantly increased both effectiveness in controlling early blight on potatoes and potato yields. Data analysed statistically using ANOVA showed increased efficacy in control of early blight of 81.23 % as compared to 59.7% for Dithane applied alone. Yields (improvement over control) were increased by 75.56 % as compared to 39.16% for Dithane applied alone.	Kenya	JAL, 2011 c.
Propiconazole (Tilt)	Leeks	Leek Rust	Codacide used with Tilt at half rate compared to Tilt applied alone at half rate showed good improvement in rust control in terms of reduced number of leaves with rust and reduced number of pustules at pre-trimming and post trimming on 1d day treatments.	UK	HRI Stockbridge, 1995 c.

Trichoderma viride *Trichoderma harzianum*		Botrytis	To evaluate the effects of surfactants on the efficiency of plant disease biocontrol organisms. Codacide at 0.1% significantly inhibited the growth of Botrytis but did not significantly affect the growth of either *Trichoderma* species. Other surfactants used had a negative effect on the growth and development of *Trichoderma*.	UK	University of Plymouth, 1999.
Vinclozolin (Ronilan Fl)	Dwarf beans	Botrytis/Sclerotinia	To compare the efficacy of Ronilan at a arrange of rates, with and without Codacide for the control of Botrytis/Sclerotinia in dwarf beans. Meaned over rate, Ronilan and Codacide gave significantly better Sclerotinia control than Ronilan applied alone.	UK	Microcide Ltd 1993 a.

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