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Management of Plant Diseases by Surfactants

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Abstract: Plant disease management is a big challenge nowadays due to high economic losses to the important agricultural crops. The role of surfactants in crop protection has become increasingly common in agriculture sector for improving the efficacy and stability of pesticides/fungicides. Surfactants are organic compounds which modify the surface tension. The surfactant is able to reduce the surface tension of pesticide/fungicides spray and it also increase spray droplets deposition, spread as well as retention on plant surfaces. Hence, their integration in to pesticide/fungicides formulations improves the efficacy of pesticides/fungicides. In plant disease management, the surfactants are commonly used in the pesticide formulations in order to assist the delivery of the chemicals present in the formulation to the target sites either in plants, pathogens or vectors. Surfactant helps in making a good contact with the plant surfaces, increase the retention of the pesticide on the sites for long enough to get the active ingredient to be absorbed into the plants, and finally must be able to reach to the target sites of action. The surfactants are amphipathic in nature having both hydrophilic (water-soluble component) and hydrophobic (water-insoluble component) characteristics. These two components of surfactants help them to get mixed in water or some other liquids easily and to get them frequently adsorb at interfaces where they can find the most favorable energy conditions. Although, a surfactant itself has no biological activity, but it has the ability to facilitate the active ingredient (a.i.) present in the pesticide formulation to get dispersed quickly, stably and uniformly, hence improving the biological effect of the pesticide due to which there is better plant disease management.

Keywords: Pesticide, crop protection, surfactant, agrochemical formulations.

INTRODUCTION

The population around the globe is likely to keep on increasing day by day and it is assumed to reach to about 10 billion by 2,050. Therefore, food production has to be increased to feed the coming population expansion. Agricultural productivity is a matter of big concern for most of the countries in order to meet the rising demands of the population. Use of green compounds to achieve the sustainable agriculture is the present necessity. The modern agriculture has lot of innovations added in the production process. The production in the agriculture sector is being affected significantly due to several reasons among which plant diseases and pests are one of the major causes. Plant pathogens cause significant damage to agricultural crops ranging from 10-40% either before or after harvest resulting in high economic losses (Savary et al., 2019). Hence, it is very essential to manage the pests and diseases through various disease management strategies and to improve the crop yield. In order to increase the crop production, the protection has to be given which includes the use of pesticides which is a part of plant disease management strategy. Various formulations

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are being used for managing the losses caused by the plant diseases. Pesticide efficacy is also being improved due to use of novel tools which are concurrently developed in order to facilitate efficient delivery of the chemicals to target sites of plants, pathogens as well as vectors. Such novel tools comprise of nano-formulations, better spraying technology, and progresses in surfactants (Huang et al., 2018; Palma-Bautista et al., 2020)

Agrochemical formulations used for crop protection are prepared to suit a precise application. These necessitate the involvement of an adjuvant that is very much essential for preparation of the formulations as well as to safeguard its long lasting physical stability (Green, 2000). In addition to this, it also improves the biological efficiency of the formulations. An adjuvant is an ingredient that helps or alters the function of principal active ingredient (a.i.). Adjuvants enhance foliar absorption of pesticides/herbicides, defoliants, as well as growth regulators (van Zyl et al., 2014).

In the management of plant diseases, pesticides are used on a large scale. But due to various reasons, the efficient delivery of the active ingredient of the pesticide does not reach the target site of the plants. For this reason, some substance has to be added in the pesticidal formulations so that the pesticide should reach the desired target site. Adjuvants are among those substances which when added to any formulation increases the efficacy of that formulation (van Zyl et al., 2010). Therefore, the selection of any adjuvant in a formulation is very crucial (Tadros, 2005). Adjuvants have several functions related to pesticide efficiency (Green and Beestman, 2007). For the foliar absorption of pesticides, the addition of adjuvant is very essential. Generally, adjuvants are used in combination with the pesticides/fungicides to facilitate the effective delivery of the active ingredient of the chemicals to reach the target sites of action in plants, pathogens or vectors.

A surfactant, as its name indicates as ***SURF**ace **ACT**ing **A**ge**NT*** is a kind of adjuvant which is designed to enhance the wetting, sticking, absorbing, spreading, dispersing, emulsifying as well as penetrating characteristics of a pesticide solution (Buffington and McDonald, 2006). Surfactants can improve the surface-surface interactions by making micelles from natural sources like plants, animals and microbes (Rahman and Gakpe, 2008; Varjani and Upasani, 2017). A surfactant markedly affects and enhances the surface characteristics of that particular system in which it is being added (Babajanzadeh et al., 2019). The reason for addition of surfactant as an adjuvant in the formulation is to facilitate the spray solution to stick to the target surface, and enhance its spreading efficiency over it in order to cover a maximum area. In addition, it also aids in the optimization of the biological efficacy (Castro et al., 2013). A good surfactant has many characteristics which is desirable in any formulation (Fig. 1).

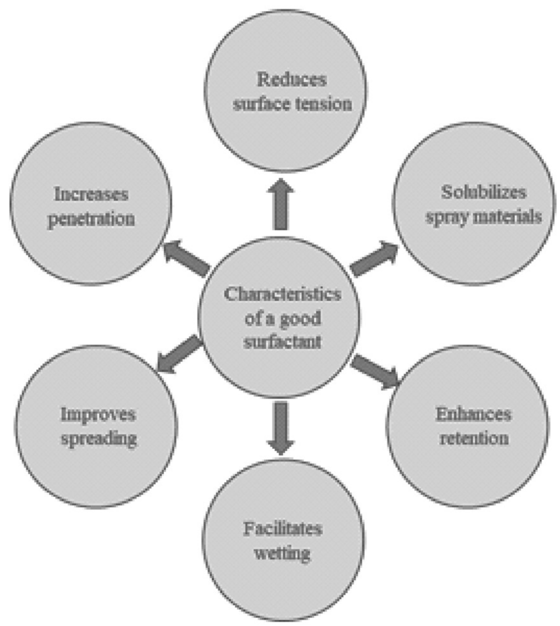


Fig. 1. Characteristics of a good surfactant

Surfactants are amphipathic in nature having hydrophilic as well as hydrophobic characteristics (Salager, 2002; Yuan et al., 2014). It acts as wetting agent in order to ensure a connection between a surface and a solution by increasing the adsorption between them and making micelle clusters during this process (Vaidya and Ganguli, 2019). As we know, that due to surface tension the ability of any substance to mix with the other substance is decreased. The surfactant has a unique property to reduce the surface tension of any liquid so that it can easily mixed in water or some other liquids. So, it can be mixed in any formulation and due to its presence in that formulation it facilitates the penetration of water or any other liquid evenly. In the soil, it also helps in absorption as well as retention of moisture.

The role of surfactants in crop protection has progressively become very essential in 21st century agriculture (Castro et al., 2013a, 2013b). A good surfactant is one which activate pesticides/ fungicides to enhance pest and disease control, assist pesticides/fungicides stick to the surface of leaves and allows pesticide/fungicide to spread on the surface of leaves.

CLASSIFICATION OF SURFACTANTS

Surfactants are mainly classified into two categories i.e. Synthetic surfactants & biosurfactants.

1. Synthetic surfactants

Synthetic surfactants are synthesized artificially. They do not have natural origin. As we know that the hydrophobic group of the surfactants is generally a long-chain of hydrocarbon, whereas the hydrophilic group is a highly polar (ionic) group. Therefore, based on the nature of the polar heads, synthetic surfactants are divided into four different types viz., nonionic, anionic, cationic and amphoteric (Fern´ andez Cirelli et al., 2008; Mariano et al., 2013). These are discussed as follows-

(a) Nonionic surfactants- Nonionic surfactant as the name indicates has no electrical charge that is why they are the most widely used surfactants in agriculture especially with regard to crop protection due to their compatibility with all types of pesticides/fungicides (Tadros, 2006; Tu and Randall, 2005). The hydrophilic nature of nonionic surfactants is caused by either polymerized glycol ether/glucose unit, therefore, these are commonly known as ethoxylated surfactants. Nonionic surfactants are used in agrochemicals as emulsifiers, detergents, dispersing agents as well as wetting agents.

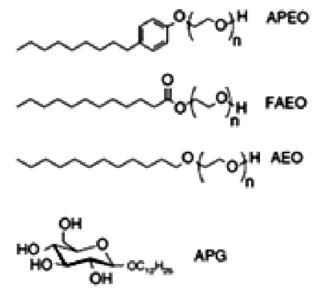
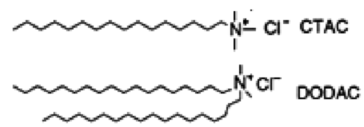
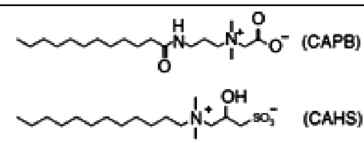
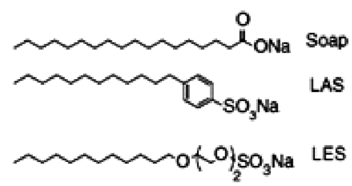
(b) Anionic surfactants- Anionic surfactants comprises of the anionic functional groups at their heads. These have a negative charge and they increase the retention of the cations. The hydrophilic groups of these surfactants contain mostly, sulfate, sulfonate, carboxylate or phosphate groups having a calcium or a sodium counter ion (Schmitt, 2001). In several formulations of agrochemicals, calcium linear alkylbenzene sulfonate is present which work as an adjuvant.

(c) **Cationic surfactants-** These surfactants consists of quaternary ammonium ions as their hydrophilic groups. These include amines and cetrimonium bromide (CTAB), (Abbott, 2018**).** These surfactants have gained a lot of importance due to its bacteriostatic properties. Due to its high adsorption capacity on wide range of surfaces, they are used widely.

(d) **Amphoteric surfactants-** These surfactants have both a +ve and a -ve charge and hence, has characteristics of an acid as well as a base. Amphoteric surfactants has the capability to react as either a cationic or an anionic therefore, they are also referred to as zwitterionic surfactants (Klein and Palefsky, 2007). They can take up either a net negative or positive charge depending upon the pH that ultimately affects wetting, foaming, detergency, etc. They have solubility in water and thus, are highly compatible with other surfactants, forming mixed micelles. They are highly biodegradable also (van Ginkel, 2007).

(e) Biosurfactants-Biosurfactants are produced by a range of micro-organisms for. e.g. bacteria and fungi. They are amphiphilic in nature consisting of surface-active molecules. They have environmental-friendly characteristics and have shown promising results in integrated disease management (D’aes et al., 2010; Raaijmakers et al., 2010). Species of *Pseudomonas*, *Bacillus*

Table 1: Types of surfactants

	Alkyl tail	Polar head	Example
Non-ionic	C_8-C_9 alkylphenol residues	$-(CH_2CH_2O)_n-OH$ n: 4–22	
	C_8-C_{20} linear or branched-chain	$-COO(CH_2CH_2O)_n-OH$ n: 4–22	
	C_8-C_{20} linear or branched-chain	$-(CH_2CH_2O)_n-OH$ n: 2–22	
	C_8-C_{20} linear or branched-chain	$-NH(CH_2CH_2O)_n-OH$ n: 2–22	
	C_8-C_{20} linear or branched-chain	Glucose	
Cationic	C_8-C_{18} linear-chain	$-N(CH_3)_3Cl$	
	C_8-C_{18} linear-chain	$-N(CH_3)_2Cl$	
Amphoteric	C_{10}-C_{16} amido-propylamine residue	$-N^+(CH_2)_2CH_2COO^-$	
	C_8-C_{18} linear-chain	$-N^+(CH_2)_2CH_2CH(OH)CH_2SO_3^-$	
Anionic	C_8-C_{20} linear or branched-chain	$-COOH$	
	C_8-C_{15} alkylbenzene residues	$-SO_3Na$	
	C_8-C_{20} linear-chain ethoxylated	$-OSO_3Na$	

and *Burkholderia* are well-known to secrete lipopeptides and rhamnolipids which have various agricultural and industrial applications. Enhanced resistance to bacterial and fungal pathogens have been conferred by lipopeptides and rhamnolipids through stimulation of plant immune system (Vatsa et al., 2010; Schellenberger et al., 2019). A variety of biosurfactants having antimicrobial properties show efficacy against huge number of the plant pathogens (Mnif and Ghribi, 2016; Penha et al., 2020). They are used as biopesticides in plant disease management because of their high biodegradability, ecofriendly nature as well as excellent production from the renewal energy resources. Various fungal plant pathogens e.g. *Fusarium* sp., *Rhizoctonia* sp., *Pythium* sp., *Alternaria* sp., *Plasmopara* sp., *Phytophthora* sp., *Botrytis* sp., etc. have been reported to be controlled by using the Rhamnolipids. The application of biosurfactants helps the plant growth promoting microorganisms to enhance the mechanism of biocontrol such as competition, antibiosis, parasitism, hypovirulence, and induced systemic resistance.

MODE OF ACTION OF SURFACTANTS

The surfactants have a particular mode of action which acts against the surface tension. There are molecules both on the interior as well as on the surface of water droplet. Those molecules which are present on the exterior of a water droplet are bind to each other with greater strength as compared to the molecules on the inside of droplet which leads to surface tension. This surface tension prevents several things dissolve or go into solution which ultimately affects wetting. By using surfactants, this surface tension is reduced and it helps the material to go into the solution and let the things wet.

As we know that surfactants generally have a two components: first is the hydrophilic head which is water-loving and polar head and second one is the hydrophobic tail which is water-hating and non-polar tail. These two components which is present in a surfactant aid in decreasing the surface tension of water. As the surface tension is reduced, it allows the pesticide/fungicide to get dispersed on the leaf surface more uniformly and to ultimately reach its target site (Fig. 2). When any unlike materials get in contact with the molecules of water, the two forces repel each other if the materials have a same charge. Similarly, if the charges are different, the two forces will get attracted towards each other. There will be no reaction at all, if no charges are there. Beading will occur because of surface tension if water is placed on the surfaces which have hydrophobic nature. Therefore, by adding surfactants, this surface tension can be reduced to a large extent.

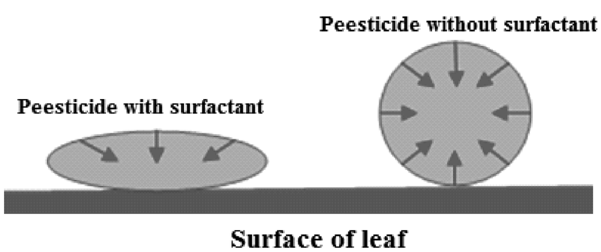


Fig. 2: Effect of surfactant on the surface of leaf increasing the spreading and retention of pesticide droplets on the leaf surface.

Applications of surfactants / Use of surfactants in combating phytopathogens

Agriculture as well as food processing industries has a great challenge to serve the high demand of food for the continuously rising population. Surfactants have potential applications in agriculture and food industry (Mnif and Ghribi, 2016). In agriculture, surfactants are used in pesticides/fungicides. It modify the characteristics of pesticidal/fungicidal spray, which includes its viscosity, particle size, wetting capacity, absorption on plant surface, evaporation rate to enhance the spread of pesticide, and reduction in photodegradation.

Apart from the use of surfactant in pesticide formulations, there are other applicatons of surfactants also in other areas also. In other industries, there are many applications of surfactants. For e.g. in the textile industry, use of surfactant in the dye help in easy penetration of dye into the fabric. Surfactants also act as cleaning agents and detergents for the preparation as well as textile treatment such as silk and wool. They also fulfill specific functions in preparing fibres and yarns, for example as smoothing agents, antistatics and adhesives.

The role of surfactants is becoming increasingly common in enhancing the performance of fertilizers. The addition of surfactants in the agroformulations enhances its efficiency and decreases the quantity of the run-off water that finally assist in saving the water which is utilized for irrigation purpose. Water-repellent soils are not able to adsorb as well as retain water effectively. Therefore, to manage water in addition to nutrients on the sandy soils is very challenging. Surfactants help in managing water and nutrients in sandy soils to a great extent.

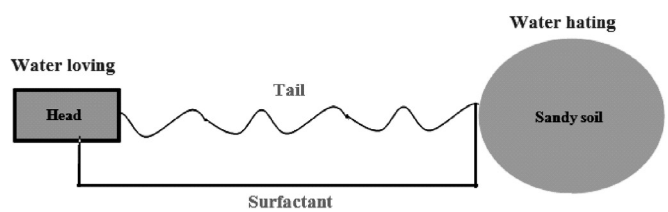


Fig. 3: Diagramatic representation of a surfactant changing the water hating sandy soil to water loving sandy soil

Another application is the stimulation of the plant immunity with the use of biosurfactants. Although, plants comprises of in-built complex defense mechanisms which gives it protection against many plant pathogens. It induces early signaling and activated phytohormones like salicylic acid or jasmonic acid, causes increased synthesis of antimicrobial compounds as well as regulate the delayed defense related responses. This leads to enhance plant immunity (Boller and Felix, 2009; Pieterse et al., 2012).

CONCLUSION

The plant pathogens and pests cause significant losses to the economically important crops. To control the pathogens and pests, pesticides are used worldwide. Nowadays, the most of the pesticides are formulated to use water. Since, the waxy surfaces of several plants, fungi and insects make it difficult for those pesticide spray solutions which are water-based to reach their target. To help break this barrier, surfactants are being added in these pesticides. Therefore, it is concluded that the use of surfactants in a pesticide solution reduces the surface tension, hence the greater will be the pesticide exposure on the plant surface and more pesticide will be able to reach its target site which in turn leads to better plant disease management.

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Conflict of interest

There are no conflicts to declare in any capacity. .

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