Crop Protection 29 (2010) 843–852

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Effects of adjuvants on deposition efficiency of fenhexamid sprays applied to Chardonnay grapevine foliage

Sybrand A. van Zyl [a], Jan-Cor Brink [a], Frikkie J. Calitz [b], Paul H. Fourie [a,c,*]

[a] *Department of Plant Pathology, University of Stellenbosch, Private Bag X1, Stellenbosch 7602, South Africa*
[b] *ARC Biometry Unit, Private Bag X5026, Stellenbosch 7599, South Africa*
[c] *Citrus Research International, PO Box 28, Nelspruit 1200, South Africa*

A R T I C L E I N F O

Article history:
Received 8 September 2009
Received in revised form
19 April 2010
Accepted 21 April 2010

Keywords:
Adjuvant
Concentration
Deposition
Fungicide
Run-off
Volume

A B S T R A C T

Adequate spray deposition on susceptible grapevine tissue is an essential requirement for effective chemical control of economically important diseases, such as grey mould, powdery mildew and downy mildew. The objective of this study was to evaluate the potential of some agricultural adjuvants to improve foliar spray deposition. Deposition quantity and quality was assessed by means of a spray assessment protocol using fluorometry, photomicrography and digital image analyses. The visual droplet rating technique developed by G Furness, Australia, was also included in initial assessments. Both assessment protocols showed that spray deposition quantity increased with increasing spray volume applications of 27 l ha^{-1} to 581 l ha^{-1} with a motorised backpack mistblower, but decreased at 698 l ha^{-1}, possibly due to run-off. Addition of selected spray adjuvants at 526 l ha^{-1} volume demonstrated improved deposition quantity and quality. Agral 90 (ethoxylated alkylphenol), BB5 (acidifier), Nu-film-P (terpene oil), and Solitaire (silicone/plant oil) significantly improved deposition on upper and lower leaf surfaces compared with the fenhexamid-only and water sprayed control. Break-thru S240 (organosilicone) and Villa 51 (alkylpolyethylene glycol ether) did not improve deposition quantity, although remarkably better deposition quality was obtained. An adjuvant concentration effect (within the registered concentration range) was evident at spray volumes of 502 l ha^{-1}, especially those retained on the upper leaf surfaces. Agral 90 and Nu-film-P effected significant improvement of spray deposition at the higher concentrations (18 ml and 50 ml hl^{-1}, respectively), but not at the lower concentrations (6 ml and 20 ml hl^{-1}, respectively). Solitaire improved deposition at the lower concentration tested (50 ml hl^{-1}), whereas reduced deposition at the higher concentration (100 ml per hl^{-1}) was attributed to excessive spray run-off. No significant improvement of spray deposition was observed for both concentrations tested with Villa 51 (50 and 100 ml hl^{-1}). Spray mixtures with adjuvants Agral 90 and Solitaire yielded similar deposition values at 500 l ha^{-1} compared with the fenhexamid-only control at 720 l ha^{-1}, but reduced deposition at the higher spray volume, possibly due to spray run-off. This study clearly demonstrated the potential of adjuvants to improve deposition quantity and quality, but highlights the necessity to match adjuvant concentrations and application volumes on the spray target to achieve maximum spray deposition.

1. Introduction

Grey mould (*Botrytis cinerea* Pers.), powdery mildew [*Erysiphe necator* (Schwein.) Burrill] and downy mildew [*Plasmopara viticola* (Berk. & M. A. Curtis) Berl. & De Toni], which are economically important diseases of grapevines (*Vitis vinifera* L.) (Bulit and Dubos, 1994), are mainly controlled by means of fungicide spray applications (Matthews, 1997). Sufficient deposition of fungicide on grapevine leaves and bunches is an essential requirement for effective chemical control of these pathogens. Grape growers invest heavily in chemical products and routine spray applications each year for disease control (Van Rooi, 2001). However, insufficient deposition of fungicides on susceptible grapevine tissue (i.e. target sites), coinciding with favourable conditions for pathogen infection, results in large losses of yield and grape quality.

Holloway (1970) and Gaskin et al. (2005) demonstrated that fungicide retention is negatively correlated with surface roughness

* Corresponding author. Department of Plant Pathology, University of Stellenbosch, Private Bag X1, Stellenbosch 7602, South Africa. Tel.: +27 21 8083721; fax: +27 865 717273.
E-mail address: phf@cri.co.za (P.H. Fourie).

0261-2194/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cropro.2010.04.017

and epicuticular wax. Gaskin et al. (2005) showed that grape foliage is moderately 'difficult-to-wet' on the upper, and very 'difficult-to-wet' on the lower surfaces. They demonstrated that surface roughness increased the contact angle of solution droplets. This can influence the rebound of spray droplets, spray run-off and results in less contact between the deposit and leaf surface (Wirth et al., 1991; Hunche et al., 2006). The water repellent cuticular waxes (Bargel et al., 2006) are an important site to consider for improvement of agrochemical wetting and retention of active ingredient deposition (Holloway, 1970, 1993; Bukovac et al., 1986; Bukovac and Petracek, 1993; Wagner et al., 2003).

Many adjuvants are reported to improve deposition of the pesticide active ingredient (Ryckaert et al., 2007) by the surfactant component in their formulations (De Ruiter et al., 1990; Gaskin et al., 2002), which may increase the wettability of droplets and spread on the target surface (Hall et al., 1993, 1998). Improved spray deposition will very probably improve disease control, as was shown in a recent laboratory study (Van Zyl et al., 2010). This study showed the importance of improved deposition quantity as well as deposition quality, which resulted in a reduction in the incidence of *B. cinerea* on grapevine leaves. In field trials conducted in New Zealand, the inclusion of an adjuvant at reduced spray application volumes improved deposition on a variety of crops (Gaskin et al., 2000a,b, 2001a,b, 2002, 2004a,b). Adjuvants may improve pesticide application from preventative high-dose and high-volume applications to a more effective preventative low-dose (Ryckaert et al., 2007) low-volume application (Gaskin et al., 2002).

It is estimated that 40–50% of foliar sprays generally do not reach the target sites on crops with commercial high volume application to the point of run-off (Matthews, 1997). These droplets normally have high contact angles with the hydrophobic leaf surface (Holloway, 1970; Gaskin et al., 2005; Bargel et al., 2006). High droplet tension and poor droplet contact area with the plant surface (possible liquid/air surface tension) means less droplet wettability (Watanabe and Yamaguchi, 1992; Wagner et al., 2003; Bargel et al., 2006). Under such conditions, droplet run-off can be expected to be very high (Holloway, 1970). Lower volume application may influence droplet size, and may increase the quantity of smaller droplet deposits (Fourie et al., 2009). According to Bateman and Jessop (2008), motorised mistblowers can achieve good deposition on cacao trees and other crops with the combination of air assistance and production of smaller droplets (i.e. without spraying to run-off). However, spray droplet retention may still be a significant factor on the water repellent plant surface (Wagner et al., 2003). Poor application efficiency might also arise from less contact between fungicide and the leaf surface waxes with low applied volumes, where small droplets can be trapped by hairs (Holloway, 1970; Wagner et al., 2003). Droplet retention can be enhanced by applying an appropriate adjuvant.

Surfactants in adjuvants have the ability to lower droplet surface tension and increase plant cuticle wettability and droplet spreading properties, which results in improved quantity and quality of deposition (Hall et al., 1993; Ryckaert et al., 2007). However, it is hypothesised from previous research that adjuvant concentration may play an important role on deposition (Van Zyl et al., 2010). Too low concentration might not sufficiently reduce droplet surface tension to ensure the spreading effect needed to improve deposition quantity and quality. On the contrary, too high an adjuvant concentration might lower droplet surface tension to the extent that run-off is increased. Spray volume might also be an important factor influencing deposition properties of adjuvant spray mixtures. Gaskin et al. (2002) found that use of organosilicone adjuvants at higher spray volumes on wine grapes resulted in less retention. Variables, such as larger droplets in combination with reduced surface tension may increase the run-off effect. Gaskin et al. (2002) highlighted the importance of matching adjuvant concentration with application volume, spray retention and distribution on grapevine target surfaces. In order to develop useful prescriptions for adjuvants by determining water volumes and adjuvant concentration, an accurate deposition protocol should be employed. A variety of methods have been used to assess spray coverage in vineyards. These methods include visual assessment on water-sensitive paper, bioassay and chemical residues recovery techniques (Holownicki et al., 2002). Uk (1977) recommended that deposition research should be done on biological targets in their natural environment, since deposition on artificial surfaces did not accurately simulate deposition on natural targets. Visual deposition assessment was greatly improved by adding fluorescent dyes to the spray mixture, followed by illumination of deposits under black (UV) light (Furness, 2000). Furness et al. (2006) developed a droplet rating chart, and used fluorescent dye to estimate the number and size of droplets per cm^2. The advantage of this method is that it is quick, cheap and easy to use. However, visual deposition is dependent on human discretion and may lack quantitative measuring and speed of measurement (Derkson and Jiang, 1995). Bioassay and chemical residue recovery techniques provide an overall assessment of the quantity of spray deposits, but residue levels alone do not give a good indication of application quality such as uniformity of spray distribution (Holownicki et al., 2002). Efficacy of agricultural chemicals is influenced by both deposition quantity (amount of deposit) and deposition quality (distribution of deposit) (Van Zyl et al., 2010). If the quality of the deposited dosage is poor, efficacy may also be poor, even if the correct quantity of chemical is impacted. Deposition quantity and quality assessment protocols were developed and validated by Brink et al. (2004) and Fourie et al. (2007), using fluorometry, photomicrography and digital analyses. Furthermore, the accuracy of these protocols has been proven in a recent study on agricultural spray adjuvants, whereas reduced *B. cinerea* incidence were most often associated with improved deposition quantity and quality (Van Zyl et al., 2010).

The objective of this study was to use recently developed deposition assessment protocols to visualise and determine the potential quantity (Furness, 2000; Brink et al., 2004, 2006; Furness et al., 2006) and quality (Fourie et al., 2007) effects of some agricultural tank mix adjuvants on foliar spray deposition as influenced by varying concentration and volume in a Chardonnay vineyard.

2. Materials and methods

Selected adjuvants were evaluated in commercial Chardonnay vineyards in the Western Cape, Stellenbosch region in the 2006/07 harvest season. The study was divided into four field trials: (2.1) determination of optimum volume delivery using a STIHL SR400 motorised backpack mistblower (Andreas Stihl AG and Co., Badstr. 115, Waiblingen, Germany), which was to be used in the subsequent trials; (2.2) evaluation of the vineyard performance of adjuvants that were previously evaluated in a laboratory trial (Van Zyl et al., 2010); and determination whether or not if (2.3) adjuvant concentration and (2.4) spray volume influenced deposition on grapevine leaves. Applications were done on vineyards with 1.4×2.5 m vine row spacing, where trials 2.1 and 2.2 were conducted on a smaller and less dense grapevine canopy [$55 \times 110 \times 840$ cm ($w \times h \times l$)] than trial 2.3 and 2.4 [$75 \times 113 \times 840$ cm ($w \times h \times l$)].

All sprayed vineyard sections consisted of 6 vines, which were sprayed from both sides of the canopy. Between spray plots, 6 buffer vines were left unsprayed, as well as an unsprayed vineyard row adjacent to each plot. Experimental layout in all trials were randomised complete block designs, where each treatment