Journal of Electrostatics 90 (2017) 45–53

Contents lists available at ScienceDirect

Journal of Electrostatics

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

Efficacy of electrostatically charged glyphosate on ryegrass

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ARTICLE INFO

Article history:
Received 8 September 2015
Received in revised form
31 May 2017
Accepted 21 August 2017

Keywords:
Ryegrass
Electrostatic sprays
Glyphosate
Efficacy
Remote sensing
NDVI

ABSTRACT

Using a TX-VK3 spray tip attached to an electrostatic sprayer operated at 483 kPa pressure, ryegrass was sprayed with glyphosate at 0.0033 kg ae ha^{-1}. Charge-to-mass ratio (Q/M) for the spray solution was 1.686 mC kg^{-1} at +10.0 kV charging voltage. Treatment efficacy was assessed using NDVI (Normalized Difference Vegetation Index) spectral reflectance values. Electrostatic charging of glyphosate significantly increased volume median diameter of spray droplets ($D_{v0.5}$ = 112.8 μm) compared to uncharged glyphosate ($D_{v0.5}$ = 106.5 μm). Ryegrass health declined 80% faster by charging the glyphosate spray solution compared to the uncharged spray.

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1. Introduction

Glyphosate (N-(phosphonomethyl)glycine), a broad spectrum, systemic, post-emergence herbicide, is used extensively for weed control in production agricultural as well as in urban, industrial and recreational areas throughout the world. It inhibits the synthesis of the plant growth hormone, EPSPS synthase, through the shikimate pathway and results in metabolic disruption and death of the plant. With the introduction of transgenic, glyphosate-resistant (Roundup Ready®) crops in 1996, glyphosate is being used nearly ubiquitously in well over 90% of all transgenic crops grown worldwide [31]. Excessive reliance on glyphosate combined with inadequate weed management practices has increased selection pressure and facilitated the evolution of natural resistance to glyphosate among several weed species including those that are generally more tolerant to the herbicide [35]. Furthermore, the emergence of weed shifts towards species that are difficult to control has transformed weed abundance and species diversity in many field crops [3,38].

The development of application methods for effectively delivering weed management chemicals to target sites in field crops is fundamental to achieve maximum efficacy as well as to mitigate spray drift. Conventional spray application of pesticides uses gravitational and inertial forces for deposition of pesticide particles onto target plant surfaces, while electrostatically charged sprays produce an electrostatic field in combination with gravitational and inertial forces to deliver the particulate matter onto the intended target areas [18]. Electrostatically charged sprays are purported to provide greater control of droplet trajectories to increase deposition and reduce downwind drift. Electrostatically charged application improved abaxial deposition on artificial targets, but deposition was substantially influenced by charging voltage, application height and target orientation [29]. Larger droplets with a smaller charge to mass ratio showed better canopy penetration than smaller, more charged sprays but gave poor deposition on abaxial surface of artificial and natural crop canopies; however, air assistance increased canopy penetration but reduced abaxial surface deposits [50]. Furthermore, field studies conducted by several researchers have demonstrated that full-scale prototype electrostatic delivery systems resulted in equivalent levels of pest suppression using 1/2-rates compared to full rates of pesticides [13,20]. Palumbo and Coates [33] found greater deposition of insecticide mixtures on the adaxial surface of terminal cauliflower leaves compared to abaxial surfaces but could not consistently detect differences in deposition or spray coverage of active ingredients on the adaxial surface of the leaves between air-assisted electrostatic, air-assisted hydraulic nozzles and standard hydraulic spray application methods. Wolf et al. [52] reported that a combination of 45 kV electrostatic charge and 50 cm nozzle spacing resulted in a 96% and 345% increase in deposition on smooth pigweed,

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http://dx.doi.org/10.1016/j.elstat.2017.08.006
0304-3886/Published by Elsevier B.V.

Amaranthus hybridus L. and giant foxtail, *Setaria faberi* Herrmann, respectively, compared to the uncharged controls in a simulated no-till wheat, *Triticum aestivum* L. stubble system.

The objective of this research was to determine whether or not it is beneficially efficacious to electrostatically charge glyphosate spray solutions to control grassy weeds.

2. Materials and methods

2.1. Chargeability study

The charge-to-mass ratio of the glyphosate solution at different voltages was studied to optimize the charge on the spray solution. Measurement of charge-to-mass ratio is fundamental to an understanding of the behavior of electrostatically charged spray solutions when inertial, gravitational and electrostatic forces work together [10,25,42,47]. The effectiveness of a charged spray solution depends upon its charge-to-mass ratio (Q/M) which describes the level of charge on spray droplets during atomization and the intensity of the electrostatic forces on the spray droplets.

Prior to the assessment of Q/M, electrical conductivity and water hardness of the tap water and the glyphosate solutions were determined using an electrical conductivity meter (Model No. EC100, Thomas Scientific, Swedesboro, NJ) (Table 1). The Q/M of 0.1% glyphosate, Glyphosate, N-(phosphonomethyl)glycine (EPA Reg. # 34704-889 – Mad Dog®, Loveland Products, Greeley, Colo.)+ 0.25% R-11® (a 90% non-ionic surfactant) Alkylphenol ethoxylate, butyl alcohol, Dimethylpolysiloxane (Wilbur-Ellis Company, Fresno, Cal.) solution prepared in tap water was measured in a spray table using the battery-powered 3-D Surface Sanitizer (Spectrum Electrostatic Sprayers, Houston, Tex.), a suspended and electrically isolated copper mesh screen and a microammeter (Fig. 1). The portable electrostatic spraying system consisted of a 4.0 L spray tank containing the spray solution, a diaphragm pump, a 12-V battery, a custom power supply (0 to +10 kV), a pressure gauge, a pressure regulator and a switch for activating the charging system (Fig. 2). A TX-VK3 spray tip (http://www.teejet.com/literature_pdfs/catalogs/C51A/banding_nozzles.pdf) was mounted on the spray gun [44]. A 1-m^2 copper mesh screen was suspended inside of a spray table from the top with two rubber straps that had metal S-hooks attached to each end (Fig. 1). An insulated 16 gauge wire was alligator clipped to the copper mesh screen and then to the positive input of a microammeter (EXTECH Instruments, Model EX330, Melrose, MA). The negative input of the microammeter was connected to an electrical ground. A+0.10 kV DC custom power supply was used to charge the spray solution. The spray solution was charged to 0 kV initially, sprayed on the copper mesh screen and the return current was recorded (Table 2). The charge was then increased by +1 kV each time and the resulting return current was recorded. This was repeated up to +10 kV. The power supply was then set at the voltage that provided the highest return current, in this case, +10 kV, which maximized Q/M. Charge-to-mass ratio of the spray solution was calculated according to the following equation: $Q/M = I/M_L$ where Q/M = charge-to-mass ratio (mC kg^{-1}), I = measured return spray current (μA) and M_L = liquid mass flow rate g s^{-1}. The liquid mass flowrate was measured by collecting

Table 1
Electrical conductivity and water hardness of tap water and glyphosate solutions used in the study.

Solution	Electrical Conductivity (μS)	Water Hardness (ppm)
Uncharged water	920	462
Charged water	920	462
Uncharged glyphosate	1084	545
Charged glyphosate	1084	545

Water solution temperature was 22.0 °C.

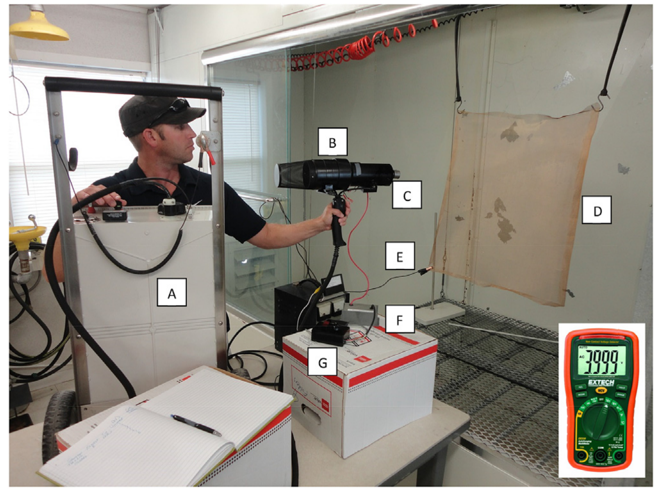

Fig. 1. Charge-to-mass ratio study of glyphosate in a spray table. Shown in the photo are: A) Electrostatic spray unit, B) Spray gun, C) Charging electrode, D) Copper mesh screen, E) 16 Gauge wire for return current, F) +10 kV power supply, and G) Voltage regulator with LED voltage display. The microammeter is shown in the inset.

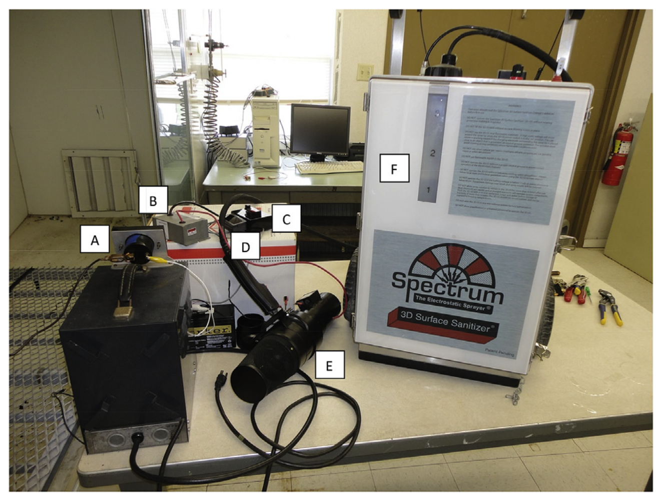

Fig. 2. The Electrostatic sprayer (3D Surface Sanitizer) used in the study for spraying ryegrass. Shown in the photo are A) Microammeter, B) +10 kV power supply, C) Voltage regulator, D) LED voltage display, E) Spray gun with integrated nozzle, and F) Electrostatic spray unit with spray tank, Power switch, Pressure gauge, Pressure regulator, Battery and diaphragm pump.

Table 2
Charge-to-Mass ratios for 0.1% glyphosate +0.25% R-11 solutions using the Spectrum 3D-SS electrostatic sprayer fitted with TX-VK3 nozzle.

Voltage (kV)	Return Current (μA)	Q/M (mC kg^{-1})
1	0	0
2	0	0
3	0.2	0.057
4	0.5	0.143
5	0.9	0.257
6	1.5	0.429
7	2.5	0.714
8	3.3	0.943
9	4.5	1.286
10	5.9	1.686