Comparison of Electrostatic and Spinning-discs Spray Nozzles on Wheat Weeds Control

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Abstract: Electrostatic spraying is the method that is noted for improving the spraying efficiency and droplet deposition. The efficacy of electrostatic charge and spinning-discs spraying were assessed for the application of 2, 4-D to control weeds in irrigated wheat. Sprayer nozzle performance was evaluated in terms of wheat grain yield (*Ghods* variety), weed shoot biomass, and wheat residual (straw) at the research farm of Shahrekord University in 2007 and 2008. The results indicated that electrostatic spraying gave better weed control. Spray penetration through dense weeds enhanced with electrostatic charging. The spinning disc nozzle decreased water use and so was cheaper to operate, but it did not significantly improve herbicide efficacy, especially in dense canopies compared with the electrostatic charge.

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1. Introduction

As summarized in the foregoing review, there have been significant advances in the research and development of electrostatic-spraying technology for beneficial agricultural and biological applications throughout the 20th century (Law, 2001). Hislop (1987) concluded that different application methods and droplet size spectra produced by hydraulic nozzles make relatively little difference in spray partitioning between different parts of the canopy and that canopy density or growth stage is of much greater importance. Coarser sprays are recommended to enhance canopy penetration, although optimum spray quality for penetration is probably specific to the canopy architecture (Spillman, 1984). When spraying into a no-till canopy, droplet interception by the stubble should be minimized and capture by the target weed maximized. These two goals may not be reconcilable because sedimentation and impact on stubble and weeds may be governed by the same criteria. Additionally, because canopies differ in texture, morphology, orientation, and depth, generalization is difficult (Bache and Johnstone, 1992). Grain yield losses due to weed competition in the wheat crop are estimated to be 25% (Montazeri *et al.*, 2005). The importance of better herbicide application equipment has been reported by Shaw (1982) for integrated weed control management. Such equipment could decrease chemical and water application per unit area. A spinning disc nozzle is suggested as a tool to reach such objectives. Uremis *et al.* (2004) stated that spinning disc nozzles with a reduced spray volume did not improve weed control and gave inadequate weed control with reduced dosage of herbicide. Spinning disc nozzles are recommended for both weed and insect control to meet the goals of integrated pest management systems. Although integrated weed management has been used for over a decade, weed management practices still need to be improved to achieve its goals. Based on Sikkema *et al.* (2008) study, the optimum nozzle type, water carrier volume, and spray pressure is herbicide and weed species-specific.

Diverse crop rotations, competitive cultivars, higher crop seed rates, reduced row spacing, specific fertilizer placement, and cover crops have been identified as integral components of competitive cropping systems (Blackshaw *et al.*, 2006). Electrostatic charging of agricultural sprays has several demonstrated advantages over conventional application methods, the most significant being more spray deposition on the target plants and less deposition on the ground (Bailey, 1988). Physical characteristics of charged sprays, such as their predisposition to deposit in the upper regions of the crop canopy (Morton, 1982), contribute to erratic pest control and have required that canopy penetration are an important part of the evaluation of such technology. Because most electrostatic charging has been done on naturally sedimenting sprays, the use of hydraulic pressure or air assistance has been suggested as a means of enhancing the penetration characteristics of such sprays (Hislop, 1988). The combination of 45 kV electrostatic charge and 50 cm nozzle spacing produced maximum spray deposition on weeds and increase in deposition compared to the uncharged controls (Wolf *et al.,* 2000). Use of electrostatic sprayers has been studied for agricultural spraying (Kirk *et al.,* 2001, Kang *et al.,* 2004). Deposition of charged sprays on leaf abaxial (underside) and adaxial (upper) surfaces as influenced by the spray charging voltage, application speed, target height, and orientation parameters was studied in the laboratory by Maski and Durairaj (2010). Results showed that electrostatically charged spray improved the underside (abaxial) and overall deposition. Electrostatic spraying of pesticides was not successfully commercialized because of the higher cost of equipment and the relatively small coverage, especially on cereals. The latter was due to less penetration in to the crop canopy although the charge on small droplets was effective, which increased deposition and reduced downwind drift (Allen *et al.,* 1983; Lake and Marchant, 1984). The aim of this study was to investigate the effectiveness of different herbicide application methods of electrostatic charge and spinning-discs under natural weed flora in the irrigated wheat field of Shahrekord University region, Iran.

2. Materials and Methods

An air-assisted electrostatic induction spray charging system for water-based liquids designed at the Agricultural Research Engineering of Jehade-Isfahan, Iran was used (Fig. 1). That required a high velocity air flow (30 m s^{-1}) within the spraying head assembly to keep the charging electrode (8 kV) from accumulating water and then earthing the electrode. Earthed electrodes close to the spray had absorbent tubes along their lower edges and a suction system to recover spray liquid attracted to the electrodes.

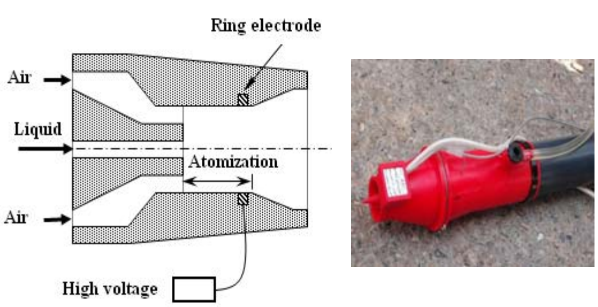

Figure 1. Electrostatic induction spray head

The charging nozzle consisted of a circular electrode and fluid jets. The high-voltage generator supplied high electric potential to the nozzle's electrode. The discharge rate of spray liquid was constant. A regulated quantity of spray liquid to the nozzle's individual fluid jets was supplied via spray liquid distributor. Two field experiments were carried out on irrigated wheat (*Triticum aestivum* L.) at the research farm of Shahrekord University in 2007 and 2008 to investigate the efficiency of different sprayer's nozzles on weed control in wheat grain yield, *Ghods* variety. A low volume spinning disc with the disc speed of 2000 rpm, *HERBI-4* (Micron Sprayers Ltd., UK) and electrostatic charge sprayer Jehade-Isfahan, Iran were used to spraying 2, 4-D at tillering stage of wheat to control broadleaved weed in cultivated wheat. Plot size measured 30×30 m, separated to be a distance of 5 m. Seedbed preparation was accomplished based on common local practices. Wheat population was 400 plants m^{-2}. The spray head was kept about 200 mm above the ground or weed foliage. The effective rate of 0.7 kg ha^{-1} 2, 4-D manufacturer's recommended dose, was used in all treatments. Sprayers were operated at a speed of 0.75 m s^{-1} at air temperatures of 20-25 ^{0}C and a relative humidity of around 36%. The wind speed at 2 m above the ground level was measured at 1-2 m s^{-1} using a direct reading cup anemometer, and the temperature and relative humidity were measured by a psychrometer whirled in the shade. Micron sprayers had a gravity feed reservoir and were powered with 6-V DC batteries. Weed population was measured separately for each quadrate to be counting the number of weeds and shoot weed biomass. Wheat grain yield were measured at maturity stage.

Water sensitive papers coated with Bromo Phenol Blue (30×100 mm) were used to determine drop density and size when the herbicide was applied. The water sensitive papers were evaluated using standard cards in WINDIAS software, Delta-T devices LTD, UK. Weeds shoot biomass was measured for each replicate of spray applications. The wheat yield was measured at crop maturity by hand harvesting the plots. The yields were adjusted to 13-14% moisture content. At harvesting time, all weed species were cut separately from soil surface and weighed. The effectiveness for herbicide on wheat crop was evaluated to be measuring wheat grain yield and weed shoot biomass. ANOVA from RCBD design was used for all data analyses with five replications. All the data met the assumptions of normality, so transformations of the data were not necessary. Significant mean values were tested with LSD at P<0.05.

3. Results and Discussion

The greater weed density and more variation of weed species were observed in the second year compared to the first year of the experiment (Table 1). *Bromus sp.*, *Convolvulus arvensis*, *Galium sp.* were the most common weeds in the first year of the experiment and *Geranium sp.*, *Descurainia sophia*, and *Bromus sp.* were the most infested weeds in the second years of the experiment. According to the analysis of variance, spraying herbicide on the wheat grain yield was significantly affected ($P<0.05$), but no significant differences were observed as a result of sprayer nozzles. The lowest yield was obtained with control treatment that had no spraying (Table 2).

Table 1. Weed composition of cultivated wheat in two years of the experiment

Year 2007	Year 2008	
Bromus sp.	*Vaccaria sp.*	*Descurainia sophia*
Convolvulus arvensis	*Anchusa sp.*	*Cirsium arvense*
Erodium sp.	*Cenesio vulgaris*	*Solanum nigrum*
Galium sp.	*Thlaspi arvense*	*Taraxacum officinale*
Centaurea cyanus	*Chenopodium album*	*Bromus sp.*
Cynodon dactylon	*Lactuca scariola*	*Geranium sp.*
Vicia villosa	*Cynodon dactylon*	*Vicia villosa*
Vicia sativa	*Centaurea cyanus*	*Convolvulus arvensis*

Table 2. Wheat grain yield and component yield (straw) of wheat in two years of 1 m^2 quadrate

	Spinning-disc	Electrostatic charge	Control
Wheat yield, g m^{-2}			
2007	419±61.4 ab	422.3±65.8 a	285.2±77.8 c
2008	358.3±90.1 abc	380.2±91.3 ab	281.1±92.8 c
Straw, g m^{-2}			
2007	371.6±122.5 bc	312.1±110.4 b	549±151.3 ab
2008	506.1±84.1 abc	455.5± 98.4 a	545±137.1 ab

a-c Different letters in the pair rows shows significant difference, LSD 5%.

± Estimates standard deviation based on a sample in 5 replications.

It would be imprudent to extrapolate results from the present study to other species or herbicide mixtures because the demonstrated deposit size effect is likely dependent on the properties of the active ingredient or the adjuvant included in the mixture. Some spray components may have phytotoxic effects at high concentrations per unit leaf area, which may become important with large, no spreading deposit sizes (Wolf *et al.*, 1992). Previous research showed that the deposition was substantially influenced by factors such as charging voltage, application speed, plant target height, and target orientation (Maski and Durairaj 2010). Chemical weed control reduced weed competition in wheat, thereby giving the crop a better growing environment for enhanced growth and development. The results for weed control with spinning disc nozzles varied from poor to acceptable control when used in combination with herbicides or other agents compared with conventional nozzles (Walker 1986; Mohan and Nelson 1982; Scoresby and Nalewaja 1982). In our study, no significant differences were observed among different spraying methods. Due to more competition, grain wheat yield generally was lower in 2008 compared to in 2007. The varied relationship between the density of weeds and crop yield can be explained partially with the different environmental conditions during the growing season prevailing in two years. Weed dry matter production was the least in 2008 and the most in 2007 (Table 3). These results are in agreement with those reported in Mason *et al.* (1998). The plants may not have been conductive to electric charges and may, therefore, not have been a preferred ground for the charged spray compared to other weeds.

Table 3. Weeds biomass and weeds number in cultivated wheat in two years of 1 m^2 quadrate

	Spinning-disc	Electrostatic charge	Control
Weed dry matter, g m^{-2}			
2007	69.9 abc	61.5 b	105.1 a
2008	35.3 cd	41.5 cd	85.2 ab
Number of weeds			
2007	242 ab	235 a	277.4 abc
2008	67.6 de	86.1 cde	97.2 cde

a-e Different letters in rows shows significant difference, LSD 5%.

± Estimates standard deviation based on a sample in 5 replications.

Improved deposition, distribution, and penetration of charged spray into the plant canopy considerably increase the biological efficacy (Hislop, 1988). It seems that the effectiveness for electrostatic spraying was higher in dense weed populations in the first year. The trends may be due to the fluctuation in the environmental conditions of the experimental site. Spinning disc dispense the spray solution horizontally rather than downward as do the electrostatic sprayer. Therefore, gravity is the major force moving the droplets into the plant canopy. Possibly, smaller VMDs with spinning disc nozzles in the warm and windy conditions caused the inefficiency of herbicides in weed control. Buhler and Burnside (1987) speculated that increased weed control at larger droplet sizes may be due to greater canopy penetration of the herbicide solution. Increasing droplet frequency should increase the number of droplets penetrating the crop canopy. Droplet diameter could have effect on changing the efficacy of herbicides when applied with nozzles. Knoche (1994) reported that decreasing droplet size generally caused an increase in the performance of foliage to which herbicides had been applied, whereas decreasing carrier volume mainly caused a decrease in the performance. Droplets with small diameters can be affected with environmental conditions such as wind and temperature with drifting without reaching the target leaf surface. *HERBI-4* with 2000 rpm disc speed had a bigger VMD and had more effect, but electrostatic sprayer had lower uniformity and used more water. Pearson *et al.* (1981) found that spinning disc nozzles gave better results with 250 µm, VMD than smaller VMDs. Factors such as target (leaf) height from nozzle, target position on the plant, and plant species significantly influenced the depositional efficiency of electrostatic spraying (Sopp and Palmer, 1990). Derksen *et al.* (1991) reported that the low volume electrostatic sprayer performed better than the high volume sprayer while using only 1/25th of the carrier volume and treating the plants in one-third of the time.

4. Conclusions

Electrostatic forces on small droplets are more prominent than the gravitational forces and therefore, electrostatic charging of spray droplets can provide an improved deposition with reduced drift. The spinning disc nozzle had more droplet uniformity, but it did not significantly improve herbicide efficacy in dense canopy compared with the electrostatic charging sprayer. Spinning disc sprayers decreased water use and so was cheaper to operate, but did not improve herbicide efficacy. Spray penetration through dense weeds enhanced with electrostatic charging. If the problem of poor redistribution and poor retention of coarse sprays can be addressed, then such sprays may provide an opportunity for increasing spray penetration through a weed stubble canopy. Further work is required to identify the relative capture efficiencies of weed stubbles for a variety of sprays so that both spray penetration and retention on weeds can be optimized.

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