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EFFECT OF DROPLET SIZE ON WEED CONTROL IN WHEAT

Ali Esehaghbeygi[1]*, *Ali Tadayyon*[2], *Shahin Besharati*[1]

College of Agriculture, Shahrekord University, Shahrekord, Iran
[1] Department of Agricultural Engineering
[2] Department of Agronomy and Plant Breeding

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Abstract: The efficacy of different water volume and nozzle systems, comprising spinning-discs with two disc speeds (low volume, LV), a spinning-cage rotary atomizer (median volume, MV), a flat fan nozzle Teejet-11004 (high volume, HV), and no weed control, were assessed for the application of 2,4-D to control weeds in irrigated wheat. The herbicide was applied at the tillering stage of cultivated wheat, Ghods variety. Sprayer nozzle performance was evaluated in terms of wheat grain yield, weed shoot biomass, and wheat residual (straw), at the research farm of Shahrekord University in 2007 and 2008. ANOVA analysis indicated that nozzle type, and the year had significant effects on grain yield and dry biomass of weeds at 5% confidence. There was a significant difference between the two years of the experiment for all variants. The results indicated that the median diameter volume using the spinning disc (low disc speed) for herbicide application, gave better weed control than others. The spinning disc nozzle decreased water use and so it was cheaper to operate. It did not, however, significantly improve herbicide efficacy, especially in dense canopies compared with the conventional flat fan nozzles. The spinning-disc had more droplet uniformity at high disc speeds compared with the cage rotary atomizer, but was more effective for weed control at low disc speeds.

Key words: spinning disc, nozzle, wheat, weed, 2,4-D

INTRODUCTION

Grain yield losses due to weed competition in wheat crop are estimated to be 25% (Montazeri *et al*. 2005). Herbicides are used for weed control in Iran, half of which is applied on wheat farms (Zand *et al.* 2007). Dadari and Mani (2005) showed that two-hoe weeding or post-emergence application of 2,4-D and oxadiazon plus propanil mixture gave the best results for weed control for wheat production in Nigeria. Utilization of post-emergence hoe weeding was impractical in irrigated wheat. In addition, Walker *et al.* (2002) showed that competitive wheat crops have the potential for improving weed control by increasing crop density to 150 plants/m^2. 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. Low volume Controlled Droplet Application (CDA) sprayers have been used as an alternative hand lance, particularly where water is limited (Cauquil 1987). 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 (Mohan and Nelson 1982; Scoresby and Nalewaja 1982; Walker 1986). 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. Different bandwidths with even flat fan nozzles showed similar grain yield, in weed control in maize. 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 the Sikkema *et al*. (2008) study, the optimum nozzle type, water carrier volume, and spray pressure is herbicide and weed species-specific. The aim of this study was to investigate the effectiveness of different herbicide application methods of volume spraying systems. The investigation was done under natural weed flora in the irrigated wheat field of the Shahrekord University region, Iran.

MATERIALS AND METHODS

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 nozzles on weed control in wheat grain yield, Ghods variety. Three hand held sprayers with rotary atomizers and one conventional sprayer equipped with standard pressurised flat fan nozzles; a low volume spinning disc with the disc speed of 2 000

*Corresponding address:
esehaghbeygi@cc.iut.ac.ir

rpm, HERBI-4 (Micron Sprayers Ltd., UK); a low volume spinning disc with the disc speed of 6 000 rpm, SKN3000 (Sabzkooshnegin Co., Iran); a median volume spinning-cage rotary atomizer with the disc speed of 6 000 rpm, KP6000-N_2 (Keshtpoosh Co., Iran); and a high volume flat fan nozzle at the pressure of 2.5 bars Teejet-11004 (Spraying Systems Co., USA) were used for spraying 2,4-D at tillering stage of wheat, to control broadleaved weed in cultivated wheat. Plot size measured 30x30 m, separated by a distance of 5 m. Seedbed preparation was accomplished based on common local practices. Wheat density 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 2,4-D manufacturer's recommended dose, was used in all treatments. Sprayer calibration was established based on the spraying volume of pure water in a constant area for each sprayer. Spinning disc sprayers were operated at a speed of 0.75 m/s and the flat fan nozzle sprayer at 7 km/h at air temperatures of 20–25°C and a relative humidity of around 36%. The wind speed, 2 m above the ground level, was measured at 1–2 m/s using a direct reading cup anemometer. Temperature and relative humidity were measured by a psychrometer whirled in the shade. Spinning disc sprayers had a gravity feed reservoir and were powered with 6-V DC batteries. The tractor-mounted sprayer worked at a 2.5 bar hydraulic pressure. Weed population was measured separately for each quadrate by counting the number of weeds and shoot weed biomass. Wheat grain yield was measured at maturity stage.

Spinning disc sprayers produce droplets with volume diameters ranging approximately over 200–300 µm, depending on solute formulation and disc or cage rotational speed. Liquid was fed gravitationally through color coded feed nozzles. Water sensitive papers coated with Bromo Phenol Blue (30x100 mm) were used to measure spray spots when the herbicide was applied. The water sensitive papers were evaluated using standard cards in WINDIAS software, Delta-T devices LTD, UK (Webb and Jenkins 2000). Shoot biomass of weeds was measured for each replicate of spray application. The wheat yield was measured at crop maturity by hand harvesting the plots. The yields were adjusted to a 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 by measuring wheat grain yield and weed shoot biomass. ANOVA from RCBD design was used for all data analyses. Five replications were made. All the data met the assumptions of normality, so transformations of the data were not necessary. Significant mean values were tested with LSD at $p < 0.05$.

RESULTS AND DISCUSSION

Sprayers specification to govern the recommended flow rate and overlapping were assessed as shown in table 1. 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 2). *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 weeds which most infested the plots in the second years of the experiment. According to the analysis of variance, the wheat grain yield was significantly affected by the spraying of herbicide ($p < 0.05$), but no significant differences were observed as a result of sprayer nozzles. The spray methods were significantly different in the two years of the study. The highest wheat grain yields were obtained using the flat fan nozzle in dense weed in 2007, and when using a spinning-disc with a low disc speed, in 2008. The lowest yield was obtained with the control treatment that had no spraying (Table 3).

Table 1. The specification of nozzle performance to govern manufacture's recommended flow rate

	Low speed spinning-disc (LV)	High speed spinning-disc (LV)	Spinning-cage (MV)	Teejet-11004 (HV)
Flow rate [l min]	166	0.133	0.143	28
Spray volume [l ha]	12.3	19.8	36.3	320
VMD [µm]	200–250	100–150	250–300	–
Disc speed [rpm]	2 000	6 000	6 000	–

LV – low volume; MV – median volume; HV – high volume

Table 2. Weed species composition in cultivated wheat from the experiment site for the two years

Year 2007	Year 2008	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 3. Wheat grain yield and its component (straw) in the two years of the experiment, in a 1 m^2, for all treatments

	Spinning-disc 2 000 rpm	Spinning-disc 6 000 rpm	Spinning-cage 6 000 rpm	Teejet-11004 2.5 bar	Control
Wheat yield, [g/m^2]					
Year 2007	416.2±66.6 ab	419±61.4 ab	363.1±111.1 abc	431.1±85.8 a	285.2±77.8 c
Year 2008	373.2±76.9 ab	358.3±90.1 abc	316.4±88.7 bc	360.3±89.9 abc	281.1±92.8 c
Straw, g/m^2					
Year 2007	316.4±153.1 c	371.6±122.5 bc	410.4±49.5 abc	320.5±110.4 c	549±151.3 ab
Year 2008	488.4±79.7 abc	506.1±84.1 abc	596.8±168.9 a	505.8± 98.4 abc	545±137.1 ab

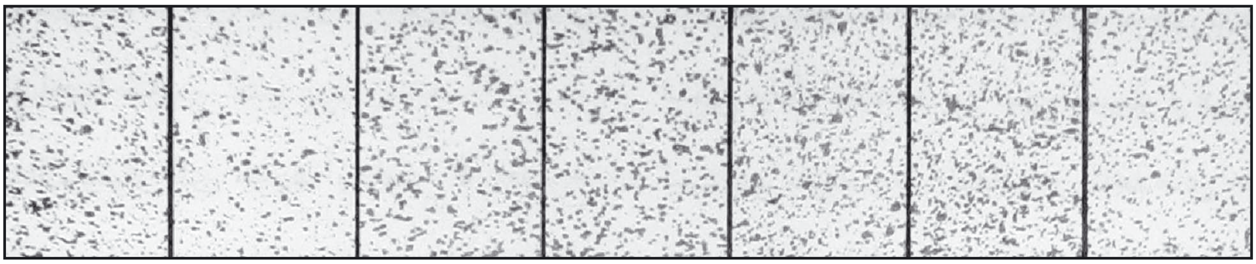
Different letters in the pair rows show significant difference, LSD 5%; $^{\pm}$ estimates standard deviation based on a sample in 5 replications

Table 4. Weed dry matter production and the number of herbicides in wheat cultivated plots in the two years of the experiment, in a 1 m^2, for all treatments

	Spinning-disc 2 000 rpm	Spinning-disc 6 000 rpm	Spinning-cage 6 000 rpm	Teejet-11004 2.5 bar	Control
Weed dry matter [g/m^2]					
Year 2007	103.8±50.1 a	69.9±47.8 abc	111.7±27.3 a	95.9±40.1 ab	105.1±29.7 a
Year 2008	21.9±6.02 d	35.3±9.8 cd	47.6±25.5 bcd	30.5±31.1 cd	85.2±34.1 ab
Number of weeds					
Year 2007	270±137 ab	242±122.5 ab	188.4±74.9 bcd	275±112.2 a	277.4±218 abc
Year 2008	69±42 de	67.6±26.6 de	111.4±36.4 e	98.1±45 cde	97.2±49.04 cde

Different letters in rows show significant difference, LSD 5%; $^{\pm}$ estimates standard deviation based on a sample in 5 replications

(a)



(b)

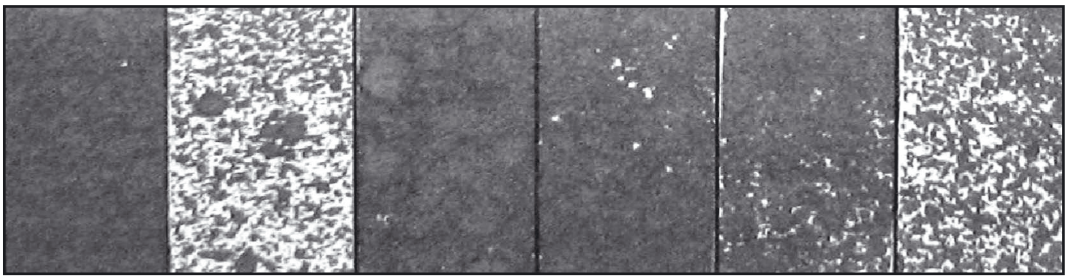


Fig. 1. Distribution pattern of spray spots on water sensitive papers
a) hand held sprayers with rotary atomizers,
b) conventional sprayer equipped with standard pressurised flat fan nozzles

Chemical weed control reduced weed competition in wheat, thereby giving the crop a better growing environment for enhanced growth and development. In our study, no significant differences were observed among different spraying methods regarding nozzle type. Due to more competition, grain wheat yield generally was lower in 2008 compared to in 2007. Differences in deposition, however, were noted – with changes in flow rate and spinning disc rpm changed droplet diameter as shown in table 1. Additionally, reducing the rpm of the HERBI-4 spinning disc resulted in increased deposition of weeds, increasing flow rate in the flat fan nozzle, Teejet-11004, and increased deposition of weeds from the sprayers. The varied relationship between the density of weeds and crop yield can be partially explained by the different environmental conditions during the growing season prevailing in the two years. Weed dry matter production was the least in 2008, and the most, in 2007 (Table 4). These results are in agreement with those reported in Mason *et al.* (1998). In addition, Inman and Kapusta (1983) found no differences between the effects of nozzles (spinning disc nozzles and flat fan nozzles) on soybean weeds when herbicides were applied either pre-emergence (alachlor and metribuzin) or post emergence (bentazone and sethoxydim).

Droplet diameter could have an effect on changing the efficacy of herbicides when applied with nozzles. Droplets with small diameters can be affected by environmental conditions such as wind and temperature. Drifting without reaching the target leaf surface may take place. In our study, a smaller Volume median diameter (VMD) was obtained with spinning disc nozzles of 6 000 rpm disc speed while HERBI-4 with a 2 000 rpm disc speed had a bigger VMD, and had more effect. The spinning cage rotary atomizer had the highest VMD value (250–300 μm), but lower uniformity, and used more water (Table 1). Figure 1 shows the distribution pattern of spray spots on water sensitive papers of hand held sprayers with rotary atomizers, and conventional sprayer equipped with standard pressurised flat fan nozzles. Similar to the current study, other studies have also reported that using a spinning disc with a low disc speed provided slightly better weed control than the flat fan nozzles, in different crops (Inman and Kapusta 1983; Walker 1986). Different results though, have been reported by other studies for maize and onion plants (Pearson and Bode 1985; Zandstra 1985; Uremis *et al.* 2004). 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. Pearson *et al.* (1981) found that spinning disc nozzles gave better results with 250 μm, VMD than smaller VMDs.

It seems that effectiveness for the Teejet nozzle would be higher in dense weed populations, but this was not observed in the results. The trends may be due to the fluctuation in the environmental conditions of the experimental site. Spinning disc or cage nozzles dispense the spray solution horizontally rather than downward as do the flat fan nozzles. Therefore, gravity is the major force moving the droplets into the plant canopy. Possibly, smaller VMDs with spinning disc nozzles, in 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. In addition, smaller droplets are used when lower spray volumes are applied. Hence, there is better spray coverage of the protected area and lower spray run-off (Doruchowski *et al.* 2002).

CONCLUSIONS

1. The four sprayers studied can be adopted for effective control of wheat weeds to obtain high grain yields.
2. The spinning disc nozzle had more spray spot uniformity, but it did not significantly improve herbicide efficacy in dense canopy compared with the conventional nozzles. Spinning disc sprayers decreased water use and so was cheaper to operate. It had high working efficiency especially at lower disc speeds.
3. Conventional sprayers, equipped with standard pressurized flat fan nozzles, increased the amount of water used.

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POLISH SUMMARY

WPŁYW WIELKOŚCI KROPEL NA ZWALCZNIE CHWASTÓW W UPRAWACH PSZENICY

W pracy przedstawiono wyniki badań nad skutecznością zwalczania chwastów w pszenicy herbicydem 2,4-D przy zastosowaniu różnych objętości wody oraz typów rozpylaczy z uwzględnieniem: tarczy rozpylającej o dwóch prędkościach obrotowych (LV), bębna rozpylającego (MV) oraz rozpylacza płaskostrumieniowego *Teejet-11004* (HV). Badania wykonano w latach 2007–2008, na polach doświadczalnych Uniwersytetu Shahrekord. Zabiegi przeprowadzono na nawadnianych polach pszenicy ozimej. Obiekt kontrolny stanowiła pszenica nie traktowana herbicydem. Zabiegi opryskiwania wykonano w fazie krzewienia pszenicy – odmiany Ghods. Skuteczność działania zastosowanych typów rozpylaczy oceniano biorąc pod uwagę: wysokość plonu ziarna, biomasę chwastów oraz pozostałości słomy pszenicy. Wyniki testu ANOVA wykazały, że zarówno typ rozpylacza, jak też warunki występujące w danym roku miały istotny wpływ na plon ziarna pszenicy i suchą biomasę chwastów przy 5% przedziale ufności. Wystąpiły istotne różnice zarówno pomiędzy latami badań, jak też ocenianymi parametrami. Stwierdzono, że zabiegi opryskiwania przy użyciu tarcz rozpylających (małe prędkości obrotowe) dawały lepsze efekty zwalczania chwastów niż pozostałe typy rozpylaczy. Wykorzystanie tarcz rozpylających pozwalało na zmniejszone zużycie wody i sprawniejsze przeprowadzenie zabiegu, jednak nie wpływało istotnie na zwiększenie skuteczności herbicydu, zwłaszcza w przypadku zwartych łanów pszenicy w porównaniu do konwencjonalnych rozpylaczy płaskostrumieniowych. Przy wysokich prędkościach obrotowych tarcz rozpylających uzyskano bardziej wyrównane krople w porównaniu z bębnem rozpylającym, jednak należy podkreślić, że wyższą skuteczność zwalczania chwastów uzyskiwano przy niskich prędkościach tarcz obrotowych.