NOZZLES: SINGLE OR DOUBLE, FORWARD OR BACK, COARSE OR FINE, LOW VOLUME OR HIGH VOLUME?

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Summary

The use of double nozzles was originally proposed to improve control of fusarium headblight with fungicides. Laboratory and field experiments were conducted to study the interactive effects of travel speed, nozzle configuration and nozzle type on spray deposition on vertical artificial targets. Results showed that a combination of double nozzles, air-induced sprays, and faster travel speed increased spray retention on vertical targets by more than 100%. Wider angles separating the nozzles (60º vs 30º from vertical) increased deposition, but more for coarse sprays than fine sprays. When two spray qualities were combined in a single nozzle, leading with the coarse spray gave a higher deposit than leading with a fine spray. Overall, the front nozzles contributed more to the deposit than the rear nozzles, and increases in deposit originated mostly from the front side of the target. Under field conditions, these changes had minor, non-significant effects on disease- or weed control. When single nozzles were used, orienting them forward resulted in greater deposits than orienting them backward, and maintaining low boom heights increased deposits, as did fast travel speeds and coarser sprays. The use of low water volumes combined with very coarse sprays reduced grassy weed control.

Introduction

Fusarium headblight is a serious disease of wheat and barley in high-rainfall areas of Canada, as well as elsewhere in the cereal growing regions of the world. Fungicide applications must be correctly timed and targeted to maximize the limited efficacy of available products. The wheat head, the causal agent's site of infection, is held vertically, presenting a challenging target for a spray application, and the ideal window of application is only about 48 h for tebuconazole, the product most used in Canada on FHB.

Previous research has shown that optimal targeting of specific plant structures was accomplished with droplets moving perpendicular to the plant structure (Richardson & Newton, 2000), and that targeting efficiency improved as droplet size and velocity increased (Zhu et *al.,* 1996. Elliott & Mann (1997) showed that spray deposits on wheat heads from 8002 flat fan nozzles increased from 2.6 to 4.6 µl per head as forward nozzle inclination increased from 10º to 40º. A shorter path from nozzle to target (i.e., increased droplet velocity at the target) also increased spray deposits. Nordbo *et al.* (1993) also found that deposits on vertical pipe cleaners increased with increased wind- and travel speeds.

Research at North Dakota State University has suggested that the best way to apply fungicide sprays for control of FHB is to use a "double" nozzle (McMullen *et al.,* 1999). Their double nozzle contained two tips separated by 60º from the vertical in the fore/aft direction, and was operated using a fine spray and a low travel speed. Since large areas need to be treated in a timely manner to control FHB, and that wind is nearly always a limiting factor with fine sprays, a low-drift application method that could increase both travel speeds and windows of opportunity were needed.

The objective of this study was to identify the main interacting application variables that contribute to spray deposition on vertical targets. These variables included spray quality, travel speed and nozzle angle.

Materials and Methods:

Application Method

Five lab experiments were conducted, three with double nozzle arrangements, and two with single nozzles. Nozzles were mounted on a 5-nozzle boom in a 15-m long x 5-m wide x 4-m high track room. Front and rear nozzles were fed with individual liquid supplies. Each liquid supply contained a unique fluorescent dye, which permitted the determination of the fate of the sprays originating from the front and back booms separately. Each treatment was applied to six replicate samples.

Target Material

Artificial targets were selected for this study to facilitate gathering detailed information. Plastic drinking straws (1.25 cm diameter, 11.25 cm length) were used to simulate wheat heads. Targets were arranged in two locations under the boom: under the centre of the central nozzle, and under the centre of the nozzle overlap, 25 cm beside the first location. In this manner, non-uniform patterns were averaged. Dye content was quantified using fluorescence spectrophotometry. Data were expressed as litres ha^{-1}, based on the calculated projected surface area of the targets.

Results

Experiment 1 - configuration, speed and spray quality

Averaged over all treatments, the air-induced spray produced larger overall deposits than the fine spray (120 vs 105 litres ha^{-1}). The double nozzle configuration increased deposits over the single nozzle from 84 to 141 litres ha^{-1}, with the all the extra deposit originating from the rear nozzle in the double setup. Faster travel speed increased deposits from 102 to 122 litres ha^{-1}, with greatest gains from the front nozzles and a slight loss of contribution of the rear-facing nozzles.

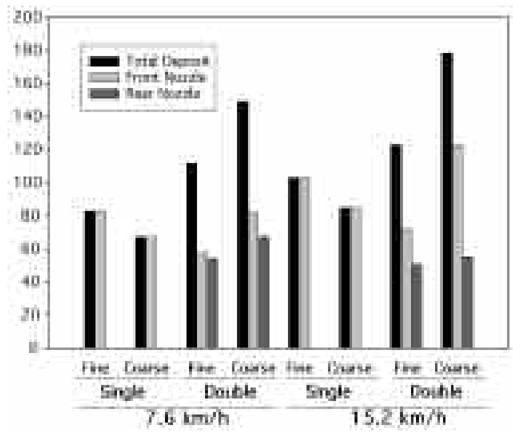

Figure 1: Effect of travel speed, nozzle configuration, and spray quality on spray deposition

The effect of nozzle configuration depended on the nozzle, irrespective of speed. With the fine spray, using a double nozzle increased deposits from 93 to 117 litres ha^{-1} on the simulated heads. With coarse sprays, deposits were somewhat lower for the single nozzle spray (76 litres ha^{-1}), but increased to 164 litres ha^{-1} with the double nozzle.

Experiment 2 – angle, speed and spray quality

Averaged over all treatments, faster travel speed increased overall spray deposits from 79 to 96 litres ha^{-1}, similar to Experiment 1. Again, the increased deposit came from the front boom, rising from 44 to 58 litres ha-1 with increased speed, with little change in the contribution of the rear boom (35 vs 38 litres ha^{-1}). Deposits were greater for the coarse compared to the fine sprays (102 vs 73 litres ha^{-1}), with increased contribution of both the front and rear boom with the coarser spray. Double nozzle angle affected spray deposit: the 60º angle increased deposits to 97 litres ha^{-1} from 78 litres ha^{-1} for the 30º angle. Both front and rear booms contributed to the increased deposit, but the rear boom contributed a larger proportional increase at the wider angle. Since the front boom had a greater contribution to the overall deposit, the wider nozzle separation in effect equalized the contribution of the front and rear boom.

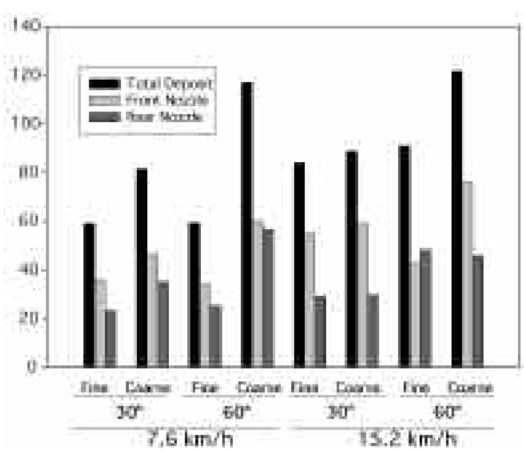

Figure 2: Effect of travel speed, double nozzle angle, and spray quality on spray deposition

The effect of travel speed depended on nozzle type as did the angle effect. The coarser spray had higher overall deposits (about 90 litres ha^{-1}) that did not increase significantly with the faster travel speed, whereas the conventional nozzles increased deposits from 64 to 78 litres ha^{-1}. The finer nozzles did not respond to angle, maintaining an average of about 70 litres ha^{-1}, whereas the coarse nozzle deposits increased from 79 to 98 litres ha^{-1} as angles increased from 30 to 60º.

Experiment 3 – nozzle mix, speed, spray quality

As in the first two experiments, faster travel speeds increased spray deposits on the vertical targets averaged over all treatments (to 130 from 102 litres ha^{-1}), with both the front and rear booms contributing to the increase. Double nozzle configurations also increased deposits, from 87 to 145 litres ha^{-1} on average. There was no significant loss of deposit originating from the front boom when a double configuration was used. The effect of nozzle type for the single nozzle configuration was also similar to previous experiments – the conventional nozzle had a higher deposit than the air induced nozzle (99 vs 74 litres ha^{-1}). When a double nozzle configuration was used, installing the coarse nozzle on the front boom and the fine nozzle on the rear boom provided a greater deposit than the opposite arrangement (154 vs 137 litres ha^{-1}), although in the former case the contribution of the front and rear boom was nearly identical (67 and 70 litres ha^{-1}, respectively).

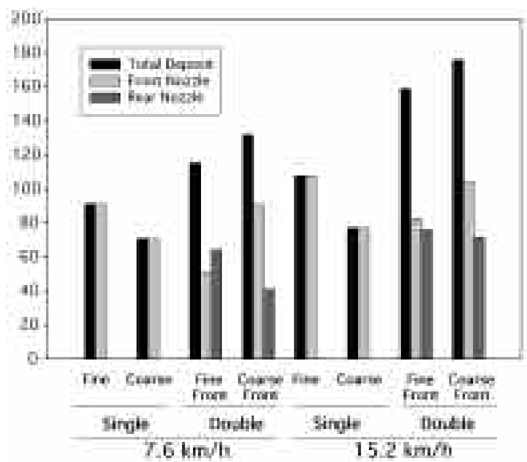

Figure 3: Effect of travel speed, nozzle configuration, and front nozzle spray quality on spray deposition

The effect of nozzle configuration depended on travel speed and nozzle type. With a single nozzle, faster travel speed increased deposits from 81 to 91 litres ha^{-1}, whereas for a double configuration, deposits increased from 124 to 167 litres ha^{-1}. For treatments where the fine nozzles were located in the front, changing from a single to a double configuration increased deposits from 99 to 137 litres ha^{-1}, whereas for treatments where the coarse nozzle were in front, deposits more than doubled, from 74 to 154 litres ha^{-1}.

Deposit uniformity

Averaged over all experiments, 65% of the total deposits with a single nozzle configuration were found on the front side of the simulated head. With a double nozzle configuration, deposits on the front side were 56%. Therefore, a double configuration increased deposit uniformity when defined as the ratio between the two sides of the target. There was a slight uniformity advantage when travelling at the slow (54% on front) compared to the fast speed (58%), and this was especially evident for the finer double sprays. For example, the slow fine double spray deposited 48% of its dose on the front side of the artificial head, which increased to 55% at the fast speed. The coarse sprays were less uniform, with 59% and 62% of the dose deposited on the front at the slow and fast speeds, respectively.

In a double nozzle configuration, the front nozzles provided more than half of the total deposit, 55% for conventional nozzles and 61% for air-induced. The faster speed did not affect the contribution of the fine nozzle, but increased the contribution of the air-induced front nozzle to 64%. Although the proportion of the spray originating from the front nozzle increased, the actual dose delivered by the rear nozzle did not change appreciably. Therefore, the increased contribution achieved with of the front nozzle at the faster speeds comes only at the cost of uniformity. Wider nozzle angles increased the equity of contribution between the two nozzles.

Experiment 4 – Effect of single nozzle angle and nozzle type on spray retention

With a single nozzle configuration, deposition onto a vertical straw was significantly affected by both nozzle angle and nozzle type. Angling the nozzle forward or backward improved deposition compared to the vertical orientation. The largest deposit was obtained with a forward angle of 60º, on average 85% greater than the vertical orientation and 40% greater than the same angle oriented backwards. Faster travel speeds increased vertical deposition but to a greater extent for finer sprays and those oriented forwards.

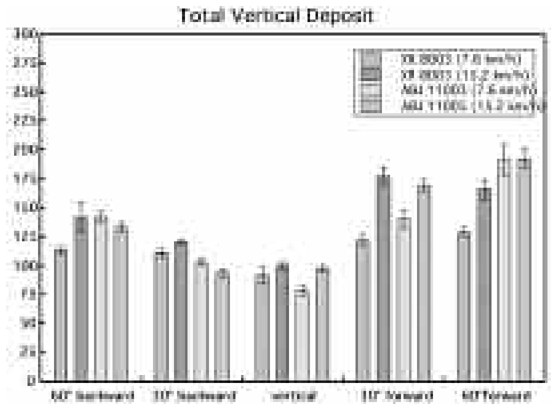

Figure 4: Effect of single nozzle angle and nozzle type on spray deposition on vertical drinking straws.

Experiment 5 – Effect of single nozzle boom height, travel speed, and spray quality

Boom height had a strong impact on deposition on the front side of straw. On the average, the 75 cm boom height had 50% lower deposits than the 45 cm height, and the 30 cm height had 40% greater deposits. Fine sprays had, on average, 20% lower deposits than Medium sprays, whereas Coarse sprays had 8% greater deposits. Faster travel speeds increased deposits by about 20% on average, but the benefit of faster travel speed was greatest for the higher boom height.

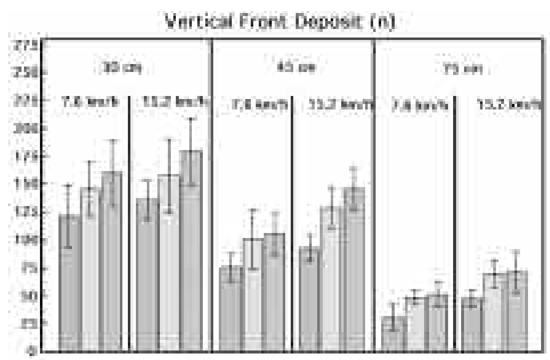

Figure 5: Effect of single nozzle angle and nozzle type on spray deposition on vertical drinking straw.

Discussion

These data show that double nozzle configurations have the potential to increase the total deposit and its uniformity on artificial vertical targets. The initial rationale for this work was to improve fungicide coverage on wheat heads, but the concept may also have potential for herbicides on grassy weeds. It has been recognized that herbicide effectiveness may be compromised when coarse sprays are employed in this situation (Wolf, 2000, Nordbo *et al.,* 1995), and a double configuration may increase overall deposits of coarser sprays.

Single nozzles deposited about 35% of their dose on the back side of the vertical targets, likely due to aerodynamic turbulence around an individual simulated wheat head. In a double configuration, both the front and rear facing nozzles contributed just under 20% of their dose to coverage of the back and front side of the head, respectively. When single nozzles were used, greatest benefits to vertical target deposition were obtained with nozzles oriented forwards, travel speed increased from 8 to 16 km/h, and booms kept low.

As is often the case, the biological implications of spray retention data are difficult to predict. In field studies, neither grassy herbicide efficacy nor chickpea fungicide efficacy was improved with a double-nozzle configuration. For the chickpeas, greater water volume decreased disease significantly and increased seed yield. In two years of field studies, changes in nozzle configuration as described in Experiment 1 failed to demonstrate significant effects on FHB disease severity, wheat grain yield, or seed quality with tebuconazole (data not shown). In biological systems, the role of crop susceptibility, disease pressure, and inherent fungicide effectiveness may often outweigh even the impressive gains in deposition suggested by these studies. However, application methods that present a greater dose in a more uniform fashion can position the applicator for increased fungicide performance when these other external variables permit.

Acknowledgements

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