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Evaluation of Fan-Pattern Spray Nozzle Wear Using Scanning Electron Microscopy

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Summary: Worn nozzles on spray equipment severely affect the efficiency of crop management systems while causing unnecessary pesticide contamination of non target areas. Scanning electron microscopy (SEM) that has been applied for direct measurement of pesticide deposition, was used to observe worn and unused brass and stainless steel fan-pattern spray nozzles. Wear and other changes were observed in both nozzle materials. Scanning electron microscopy can provide nozzle manufacturers with greater insight and needed information on nozzle mechanics to improve performance. More reliable delivery of pesticide spray should enhance integrated pest and disease management and crop protection for growers.

Key words: pesticide application, environmental concerns, application technology

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Introduction

Integrated crop management systems require delivery of disease and insect control agents, to specific target surfaces, such as leaves, stems and roots (Hall 1988). Nozzle orifice wear is one factor that can subtly alter the performance of crop management systems (ASAE 1991), whether conventional synthetic-chemicals or biological formulations are used. Ozkan *et al.* (1992) found that nozzle wear, which is largely determined by the nozzle material, changes droplet size and spray pattern. Droplet size significantly affects control of greenhouse whitefly (Adams *et al.* 1987), plant parasitic mites (Munthali 1984), powdery mildew fungus (Frick 1970), and numerous other pests and diseases. In addition, nozzle wear causes changes in flow rate and spray pattern, resulting in ineffective and imprudent pesticide use. Inefficient and insufficient delivery of pesticides to target surfaces results in waste of active ingredients and decreased deposition potentially leads to increased costs. In addition, misapplication of chemical control agents compromises worker protection and environmental quality.

Nozzles with improved and more consistent performance will lead to enhanced pesticide efficacy resulting in better disease, insect, and weed control, and reductions in conventional pesticide usage. Reduced pesticide usage results in improved safety, worker protection, enhanced environmental quality, and safer food supplies with increased profitability for the grower.

Little is known about the actual mechanism or patterns of nozzle wear (Zhu *et al.* 1995). Previous characterization of nozzle wear by conventional light microscopy (LM) was limited by low optical resolution and minimal depth of field (Ozkan 1992). Krause *et al.* (1994) reported that the use of scanning electron microscopy (SEM) improved visualization of nozzle wear. The purpose of the current study was to determine whether SEM could be used to evaluate and elucidate nozzle wear directly.

Materials and Methods

Brass (TeeJet 8002) and stainless steel nozzles (TeeJet XR 8002 VS) (TeeJet Spraying Systems Co., Nuevo, Calif., USA) were worn for 100 h using a test procedure and nozzle wear testing device developed by Reichard and others (ASAE 1991) is outlined in the American Society of Agricultural Engineers Standard S471. A solution of 9.1 kg, Flat D®, Georgia Kaolin Co. (kaolin) (Dry Run

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Kaolin Co., Tifton, Georgia, USA) and 150 l water was used at 276 kPA (40 psi) in all tests. Worn nozzles were rinsed in distilled water and air dried following wear testing. Identical, unused nozzles were also analyzed as control treatments. Five nozzles were analyzed for each treatment. Each nozzle, supported in a specially fabricated specimen holder, was placed in a Hitachi Model S-500 SEM (Hitachi, San Jose, Calif., USA). The SEM was set at 15 mm working distance using 20 kV accelerating voltage in the secondary electron detection mode. Morphological analysis of nozzles involved obtaining digitized secondary electron images from the SEM. Scanning electron microscopy was chosen for this study because it permits high resolution and morphological microscopic characterization with greater depth of field than is possible with conventional, conventional LM. To determine the progression of nozzle wear events, another series of brass TeeJet 8002 nozzles were tested as described by Reichard *et al.* 1991. Brass nozzles were worn to produce 10, 20, 30, 40 and 50% increases in their original flow rate (5 replications/rate), and then analyzed with SEM.

Results

Scanning electron microscopy revealed nozzle configurations. Figure 1 shows an unused brass nozzle. Observations of unused stainless steel nozzles showed similar configurations with rough edges, arrows, Figure 2. Nozzles worn for 100 h observed with EBA showed definite wear patterns in brass nozzles in Figures 3 and 4. Arrows indicate the wear pattern. Stainless steel nozzles showed less wear but erosion of rough orifice edges was noted (Figs. 5 and 6). Analyses of all replications within each treatment were similar and the results shown above are representative of each treatment. Scanning electron microscopy permitted observations with a ≥ 0.25 mm depth of field. In all cases, sharp edges were observed on orifice walls before testing. After orifices were tested, these sharp edges were not observed. New, untested nozzle orifices were elliptical in shape; however, worn orifices had straight edges at the ends of the major axes. The widths of the edges increased as nozzle wear progressed.

Figure 7a-f illustrates the sequence of wear events. Figure 7a represents the unused brass nozzle and the suc-

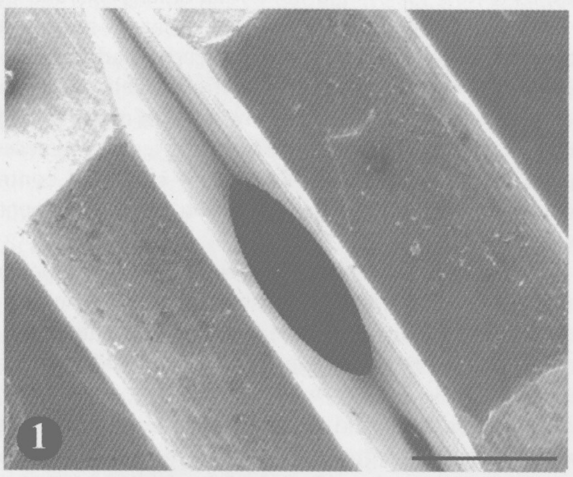


FIG. 1 Scanning electron micrograph of an unused brass nozzle. Bar = 700 µm.

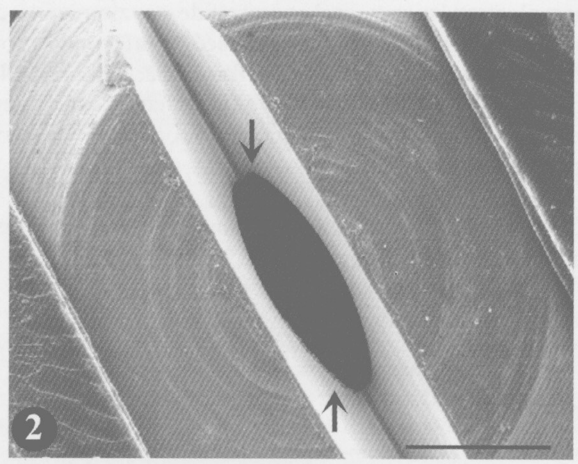
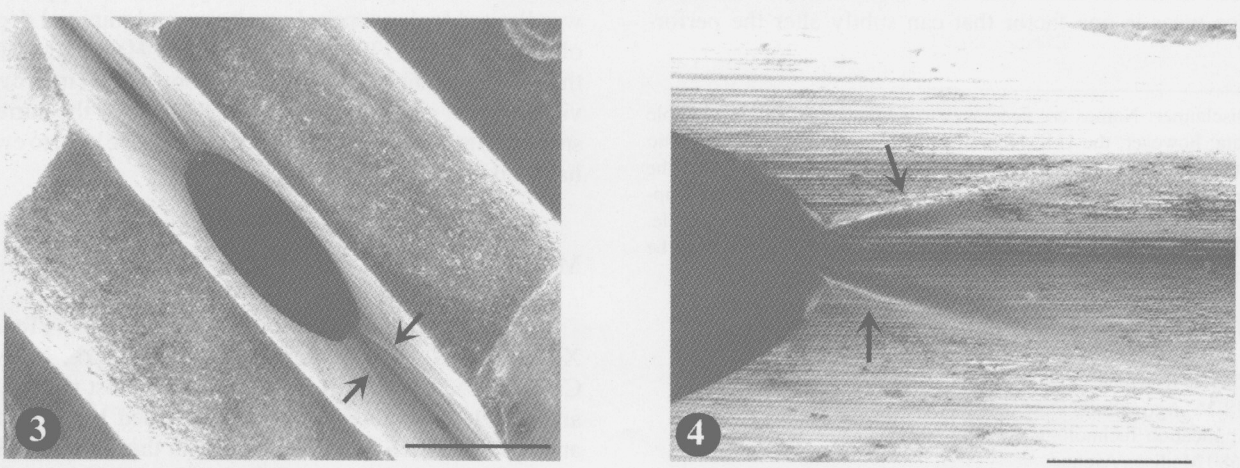
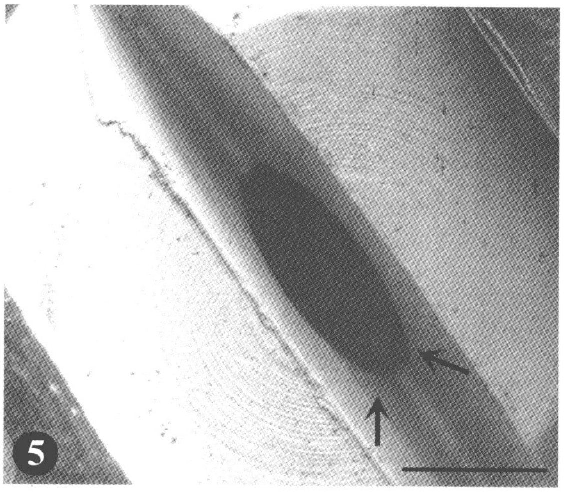
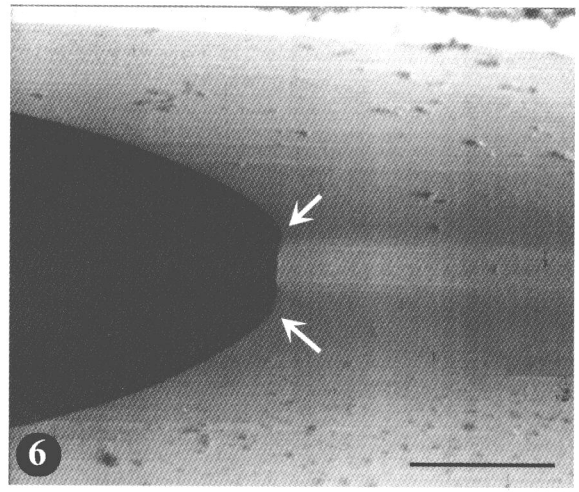


FIG. 2 Scanning electron micrograph of an unused stainless steel nozzle. Note rough edges, arrows. Bar = 700 µm.



FIGS. 3–4 Scanning electron micrograph of worn brass nozzle. Note wear patterns (arrows) and increased width of orifice. Bars = 700 and 300 µm, respectively.





FIGS. 5–6 Scanning electron micrograph of worn stainless steel nozzle. Note smooth edge, arrows. Bars = 700 and 300 µm, respectively.

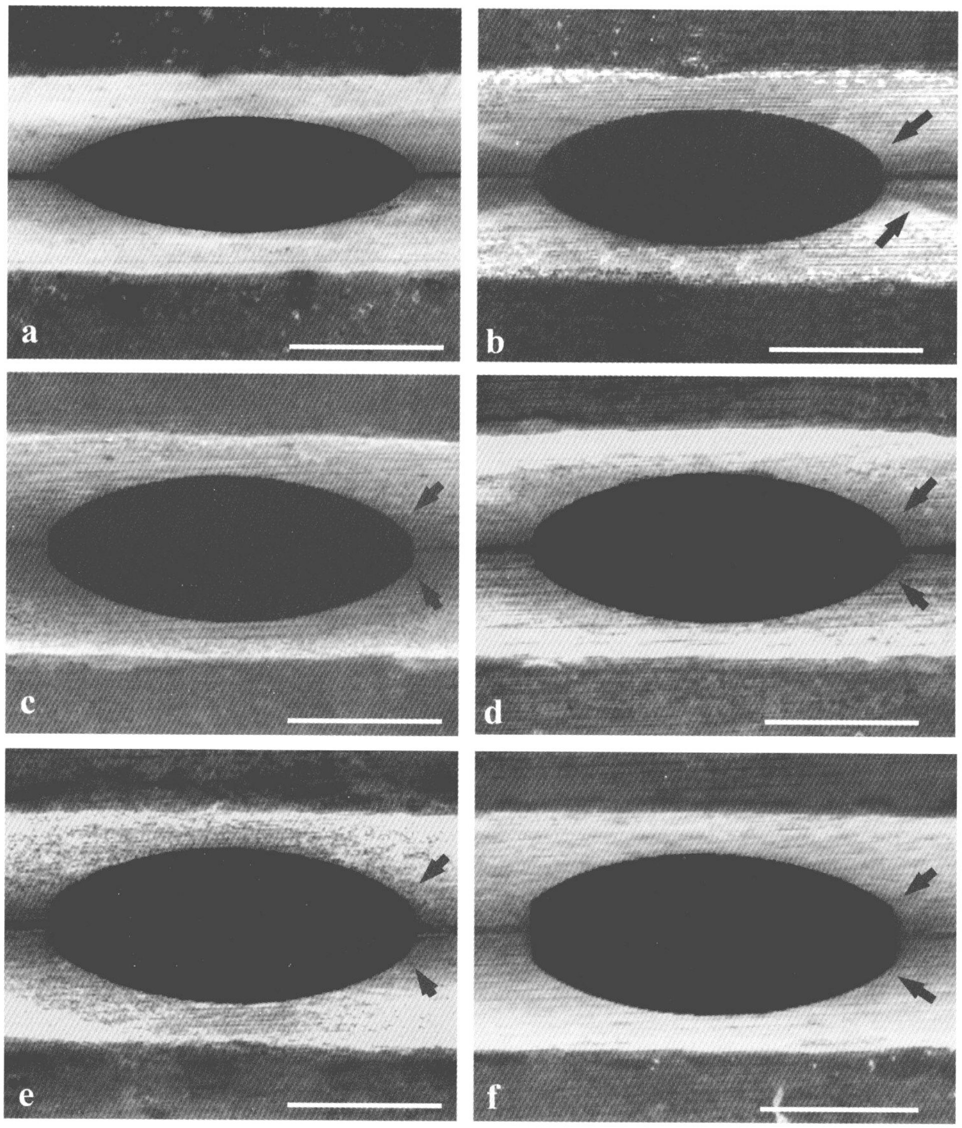


FIG. 7 Progression of a wear event using a brass 8002 TeeJet nozzle as follows: (a) Unused; (b) 10% increase in flow (note wear lines, arrows); (c) 20%; (d) 30%; (e) 40%: (f) 50%. Arrows indicate erosion of nozzle orifice ends. The orifice widths increased substantially, probably accounting for increased flow rates. Bar = 700 µm.

ceeding figures, (Fig. b–f), represent progressive wear (note arrows) in 10% increments of increased flow. Wear lines (Fig. b, note arrows) were observed on brass nozzles after 10% increments of increased flow was measured. The orifice was mainly worn outward in the direction of the minor axis. The percent increase of minor axis length was 7.7, 15.4, 26.9, 38.5, and 46.2% when the percent increase of flow rate was 10, 20, 30, 40, and 50%, respectively, while the percent increase of the major axis was only 5.1% when the percent increase of flow rate was 50%. The orifice width increased substantially, accounting for increased flow rates.

Discussion

The appearance of wear lines at only 10% wear suggests that they occurred as early events in the erosion process. Wear likely occurs due to high speed passage through the nozzles of suspended particles in pesticide formulations. Actual pesticides should be used in future wear tests to determine whether or not emulsifiable concentrates, wettable powders, or other formulations contribute to distinctive wear patterns. In addition, further nozzle wear research may yield information on spray coverage related to nozzle efficiency and deposition, retention, rebound, and efficacy of various control agents. Other analytical SEM methods, such as stereo imaging and photogrammetry, were not part of this study.

Scanning electron microscopy, as a direct, high-resolution method, permits observations at a depth of field ≤ 0.5 mm and demonstrates a new, useful, and nondestructive method of nozzle wear analysis with improved observational precision. This technique contributes to an increased understanding of wear patterns of nozzles made from different materials. Information acquired with SEM can be used by nozzle manufacturers to modify design of current nozzles leading to increased durability and consistent spray nozzle patterns. While this information demonstrates the feasibility of SEM as a technique, future investigations are needed for analyses of nozzles composed of other materials, observed before and after wear tests.

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