MICROSPRINKLER PERFORMANCE UNDER A MOVING IRRIGATION SYSTEM SIMULATOR

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Laboratory tests were conducted to determine application patterns of four inverted microsprinklers at four water pressures and three discharge heights using a center pivot irrigation simulator. Computer simulation was used to evaluate application uniformity of the microsprinklers under different water pressure and nozzle height and spacing conditions. Spinner microsprinklers had a higher application uniformity than spreader microsprinklers under moving conditions.

Microsprinklers, distribution pattern, center pivots, application uniformity

INTRODUCTION

During the past 20 years, farmers in the United States have extensively used center pivot irrigation systems for efficient and effective water application on medium and large farmlands. These center pivots can also be used for efficient chemical application. Commercial center pivot irrigation systems have large-throw-diameter sprinklers with fixed application rates along the pivot length. The application rates are controlled by a percentage timer that controls movement of the outer tower. Therefore, the application volumes of water/chemical cannot be varied along the pivot length to account for different requirements or spatial variables in different sectors of the pivot circles in the field. Under-application of water/chemical may cause decrease in crop yield. Over-application of water/chemical results in the possibility of chemical leaching and run-off, which increases production costs and could contaminate both surface and ground water. A joint project between USDA-ARS, Florence, South Carolina, and the University of Georgia was initiated to develop a computer-controlled, variable-rate center pivot irrigation system for prescription water/chemical applications within small sites in fields with the added benefit of reducing costs, increasing production, and protecting the environment.

The goal of this initial study was to investigate the possibility of using low discharge, small-wetted-diameter microsprinklers on drop-tubes for a water/chemical delivery system on a center pivot irrigation system. The system could allow variable-rate applications of water/chemical within small sectors along the pivot length based on soil, crop, weather, weed, and pest conditions.

The specific objectives of this paper were:

- to evaluate application patterns of moving microsprinklers at different water pressures and nozzle heights under laboratory conditions using a center pivot irrigation system simulator and
- to simulate the application uniformity of the microsprinklers under specific water pressure and water height and spacing conditions.

PROCEDURE

Laboratory Test

Microsprinklers are primarily designed for solid-set irrigation systems and have flat distribution patterns with distribution uniformities acceptable for tree crops, vegetables, nurseries, and greenhouse crops. The area to be irrigated is usually treated as an independent sector that needs slight or no overlap between microsprinklers. In addition, most microsprinklers are installed in an upright position. Thus, most microsprinklers cannot be adapted for use on center pivot drop-tubes, which normally require inverted sprinklers positioned at different nozzle heights and spacings for the moving condition. As a result, microsprinkler performance as affected by water pressure and nozzle height has not been evaluated for the modified conditions of drop tubes on center pivot irrigation systems. Four typical types of microsprinklers from NETAFIM[1] with 1) flat and 2) grooved spreaders, and 3) one-stream and 4) two-stream spinners were selected for the laboratory test. These could all be installed in

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[1] Mention of the vendor and the brand names does not imply endorsement by the authors, the University, or USDA-ARS to the exclusion of other vendors and brand names.

either upright or inverted positions.

The laboratory tests of the microsprinklers were conducted at the Coastal Plain Experiment Station, Tifton, Georgia. The four microsprinklers selected for the laboratory tests were a DAN7000 with a Yellow Flat spreader, a DAN7000 with a Green 12 Jet spreader, a DAN8000 with a Black Round spinner, and a DAN8000 with a Green Kiwi spinner from NETAFIM. These are typical sprinklers used in microirrigation systems for general irrigation/chemigation applications. For this initial test, a medium nozzle size (1.5 mm) was chosen for all four microsprinklers. The nominal flow rates of the 1.5-mm nozzle at pressures of 103, 138, 172, and 207 kPa were 87, 101, 112, 123, and 142 l/h, respectively. Fig. 1 presents photographs of the four microsprinklers. Both the spreader (or spinner) and the nozzle tip were mounted on a standard bridge. The Yellow Flat spreader had a slight convex pad with 12 equally divided, slightly raised lines radially distributed on the pad surface to guide water flow and maintain a consistent distribution pattern. Water was distributed horizontally after leaving the pad. The Green 12 Jet spreader had 12 small jets symmetrically located on the edge of a convex pad surface and water was ejected through the jets. The Green Kiwi spinner was a one-stream, or single-wing swivel. A stream of water was thrown into the air at a high speed by a turning force generated by water flow acting on the spinner channel. The Black Round spinner was a two-stream swivel with two channels located symmetrical to the center line of the swivel. Its operating mechanism was similar to that of the Green Kiwi spinner. The two spinners operate at relatively high rotational velocities at or above a water pressure of 103 kPa.

The application patterns of the drop-tube microsprinklers were examined outside using a moving irrigation system simulator. The simulator was a hydraulically-driven, four-wheeled, moving table with a water supply and control unit that included control valves, manually controlled pressure-reducing valves, pressure gauges, water filters, and water supply hoses. A 9-m-long, variable-height boom was attached to the table to support water supply pipes and the flexible drop tubes. The test area was a 15 m × 30 m parking lot surrounded on three sides by a field that was 2.5 meters above the parking lot and on the other side by a 5-m-tall building. The test was conducted at night at near-zero wind velocity, which was monitored by wind speed and direction sensors. The application patterns of these four microsprinklers were measured using catch cups. The catch cups were SOLO 473 ml (16 oz) clear plastic cups and the cup height and top and bottom diameters were 11.5 cm, 9.5 cm, and 6.3 cm, respectively. The catch cups were attached to a 5-m-long wood strip at a spacing of 15 cm between the cup centers. The line of catch cups was positioned perpendicular to the travel direction of the irrigation simulator with the first cup directly under the path of the microsprinkler nozzle. The microsprinkler was attached to a drop tube using a 12.7-mm (1/2") male connector. The height of the sprinkler nozzle tip above the top of the catch cup was adjusted by varying the length of the flexible drop tube. The pressure settings for the test were 103 kPa (15 psi), 138 kPa (20 psi), 172 kPa (25 psi), and 207 kPa (30 psi), and the nozzle heights were 0.6 m (2 ft), 1.2 m (4 ft), and 1.8 m (6 ft). To obtain accurate test results, two microsprinklers were randomly chosen from a group of the same type. Each microsprinkler was evaluated three times for each combination of pressure and height setting. Therefore, the application patterns of the microsprinklers reported were the mean of flow rates from the two sprinklers each replicated three times. The irrigation system simulator velocity was 1.10 m/min for all the tests.

Computer Simulation

Microsprinkler application uniformity was simulated for different nozzle spacings using a simple linear superimposition method based on the application patterns obtained from the laboratory test. The nozzle spacings for the simulation were m, 2 m, and 3 m, corresponding to about 15%, 30%, and 50% of wetted diameters for most microsprinklers, respectively. The interaction between the sprinkler distribution patterns was assumed to be negligible. Christiansen's uniformity coefficient (Cu) was used to estimate the application uniformity of the drop-tube microsprinklers for a small sector of a center pivot.

RESULTS AND DISCUSSION

Application Patterns

The application patterns of the DAN7000 with the Yellow Flat spreader for four pressures and three nozzle heights are presented in Fig. 2. At a pressure of 103 kPa (Fig. 2a) and a nozzle height of 0.6 m, the pattern had a doughnut shape and the maximum application rate occurred at a distance of 30 cm from the nozzle. An increase in nozzle height to .2 m changed the pattern from a doughnut shape to a trapezoid shape and increased the wetted diameter. At the 1.8-m height, the pattern remained similar in shape to that at the 1.2-m height except more water was distributed to the outer wetted area. The wetted diameter also increased slightly. Application patterns at 138 and 172 kPa are presented in Figs. 2b and c, respectively. The higher pressure did not significantly change the application pattern at the low height except for introduction of a valley in the doughnut-shaped curve at a distance of 15 cm from the nozzle (Fig. 2b). When the pressure was increased to 172 kPa (Fig. 2c), the application patterns at the

1.2-m and 1.8-m nozzle heights were similar to those at the 0.6-m nozzle height. If the pressure high (207 kPa, Fig. 2d), patterns for the higher nozzle height approached a triangular We also observed that the water droplet size decreased with an increase in pressure above 172 kPa, which could cause significant drift even in a moderate wind condition. The application pattern also changed slightly with time under the same test condition because of inconsistent water flow on the pad surface of the spreader, which was probably caused by variation in water pressure and the absence of a good guidance device on the spreader surface. In general, the DAN7000-Yellow Flat spreader had a small wetted diameter with good distribution nearer the center. The pattern and wetted diameter were not significantly affected by water pressure and nozzle height.

The application patterns of the DAN7000 with the Green 12 Jet spreader are presented in Fig. 3. The test was conducted under the worst orientation of the sprinkler jets on the drop tube; that is, the six water streams on one side were symmetrical with the six streams on the other side of an imaginary, vertical plane formed by the center line of the nozzle and the travel direction of the center pivot irrigation system simulator. It was shown that each half application pattern was basically a three-pulse curve which was created by the six water streams. The low pressure resulted in irregular pulse patterns at three nozzle heights (Fig. 3a), which was caused by unstable water flow through the small jets. An increase in the pressure (Figs. 3b, c, and d) resulted in a damped, three-pulse pattern curve at each nozzle height. Both the pressure and height influenced the altitude and phase of the pulse. An increase in water pressure increased the application depth, while an increase in the nozzle height decreased the application depth by increasing the wetted area. The phase of the pulse curve shifted outward with an increase of three-dimensional bar charts were used. The horizontal axis represented the nozzle spacing, the vertical axis represented the Cu, and the third axis represented the nozzle height (H).

The application uniformity of the DAN7000 microsprinkler with the Yellow Flat spreader is presented in Fig. 6. The Cu was 60 or less when the pressure and nozzle height were low (Fig. 6a). The low Cu was mainly caused by the distorted, doughnut-shape application patterns with small wetted diameters at the low pressure and low height conditions. The Cu for 1-m and 2-m spacings dramatically increased to 90 at the nozzle height of 1.2 m because of the flat, trapezoid patterns and the large increase in the wetted diameter. The Cu at the 3-m spacing could not be expected to increase because no overlap existed. When the nozzle pressure was 138 kPa or greater, both pressure and nozzle height did not considerably affect the Cu. In general, the Cu increased slightly with an increase in pressure and nozzle height (Figs. 6b, c and d). This would be expected because the application patterns were quite similar when the pressure was above 138 kPa (Fig. 2). When the nozzle spacing increased from 1 m to 2 m, the Cu decreased slowly because of the flat, trapezoidal-shaped application patterns. The wetted diameter had an upper limit. Again, there was no overlap at the 3-m nozzle spacing, which resulted in the unacceptable Cu. The Cu of the DAN7000 with the Green 12 Jet spreader was very sensitive to the water pressure and nozzle height and spacing because of the pulse application pattern (Fig. 7). No predictable pattern of Cu was exhibited for any simulation condition. In general, the closer nozzle spacing and the greater nozzle height gave the higher Cu, although it was below 90 for most test conditions.

Compared to the two DAN7000 series spreaders, the two DAN8000 microsprinklers with spinners performed much better. Cu values for the Black Round spinner approached 90 at all pressures when the nozzle height was above 1.2 m (Fig. 8). The nozzle height of 0.6 m resulted in unique trapezoidal application patterns (Fig. 5) and a low Cu at a nozzle spacing of 2 m. The increase in the nozzle height generally resulted in a slight increase in the Cu. However, the increase in nozzle spacing from m to 3 m generally caused a gradual decrease in the Cu. Green Kiwi spinner had the best overall performance (Fig. 9) compared to the Black Round, Green 12 Jet, and Yellow Flat. Increases in water pressure and nozzle height generally produced a gradual increase in Cu values and an increase in nozzle spacing often caused a gradual decrease in the Cu. However, no single parameter dominated the change in Cu.

CONCLUSIONS AND RECOMMENDATION

The application patterns of four microsprinklers were tested at four pressures, three nozzle heights, and three nozzle spacings using a linear-move center pivot simulator. application uniformity of the sprinklers at different pressure, and nozzle height and spacing conditions was simulated by computer and evaluated using the Christiansen's uniformity coefficient (Cu). Based on these results, it can be concluded that:

1. The application uniformities of the DAN7000 microsprinklers with the Yellow Flat and Green 12 Jet spreaders were highly influenced by the water pressure, and nozzle height and spacing.
2. The application uniformities of the DAN8000 microsprinklers with the Black Round and Green Kiwi spinners were not significantly influenced by the nozzle pressure, height, and spacing.
3. The DAN7000 microsprinkler with the Green 12 Jet spreader had the lowest

application uniformity and the DAN8000 microsprinkler with Green Kiwi spinner had the highest application uniformity.

4. The DAN8000 microsprinklers with the Green Kiwi and Black Round spinners had higher application uniformities than the DAN7000 microsprinklers with the Yellow Flat and Green 12 Jet spreaders.

The DAN8000 microsprinklers with Green Kiwi and Black Round spinners have potential for chemigation application via center pivot irrigation systems, especially for prescription chemigation using LEPA (Low Energy Prescription Application) center pivot drop tubes. A multiple manifold water/chemical delivery system could be developed using different microsprinkler nozzle sizes on different manifolds. Variable-rate chemigation/irrigation applications could be achieved with the center pivot irrigation systems by selecting different combinations of discrete pressures and manifolds.

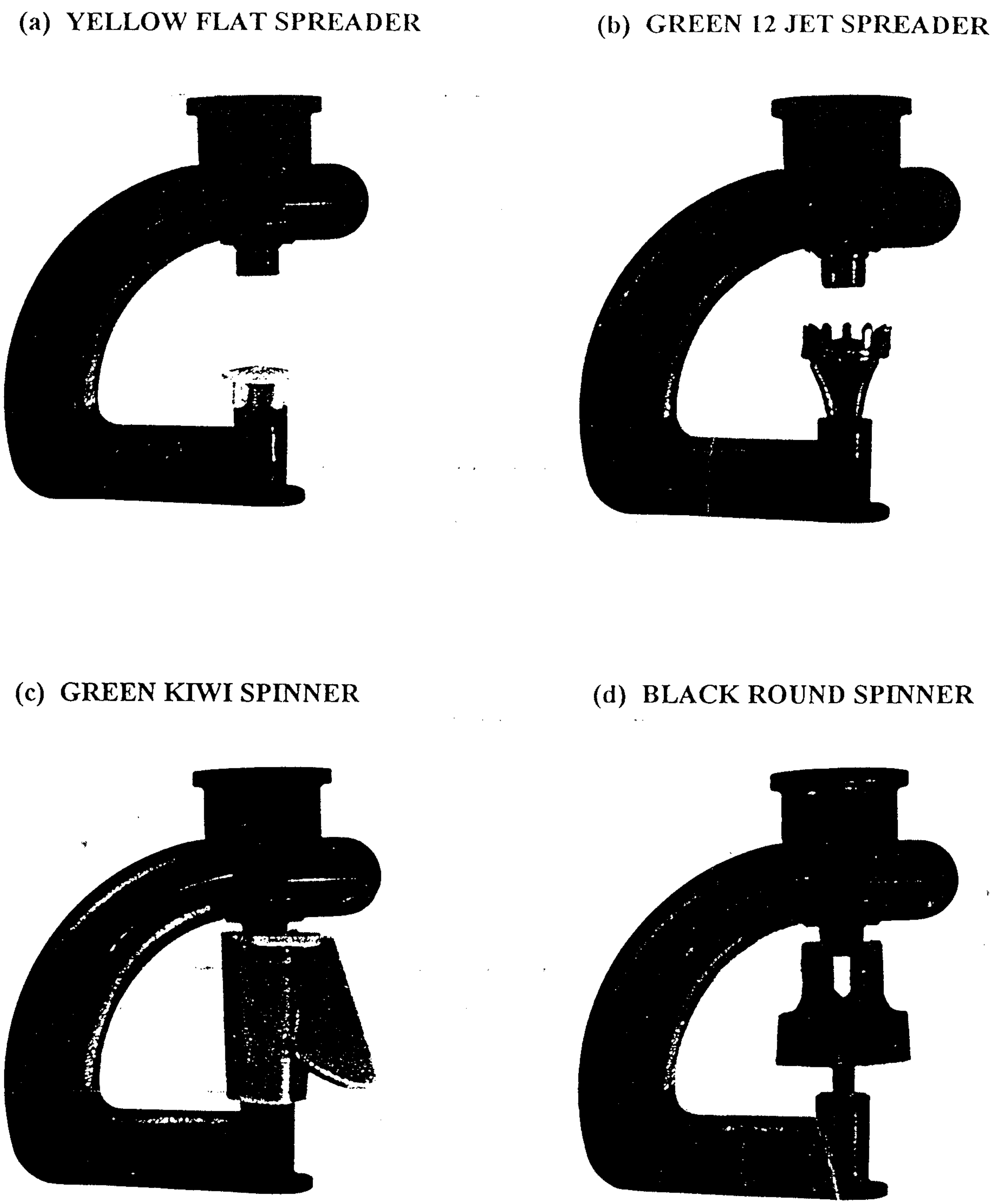

Fig. 1. Photos of the DAN microsprinklers.

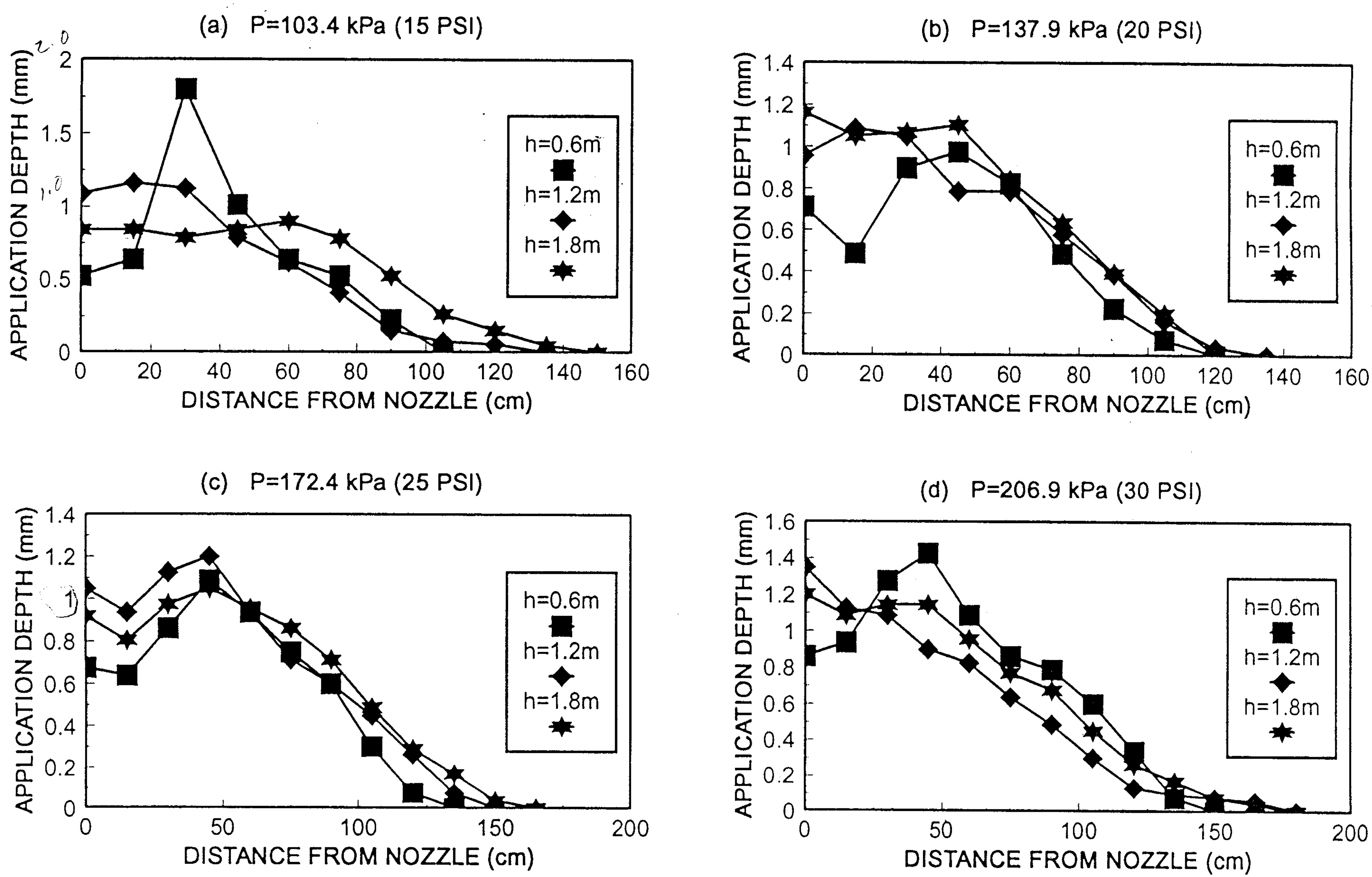

Fig. 2. Application pattern of the DAN7000 microsprinkler with a Yellow Flat spreader.

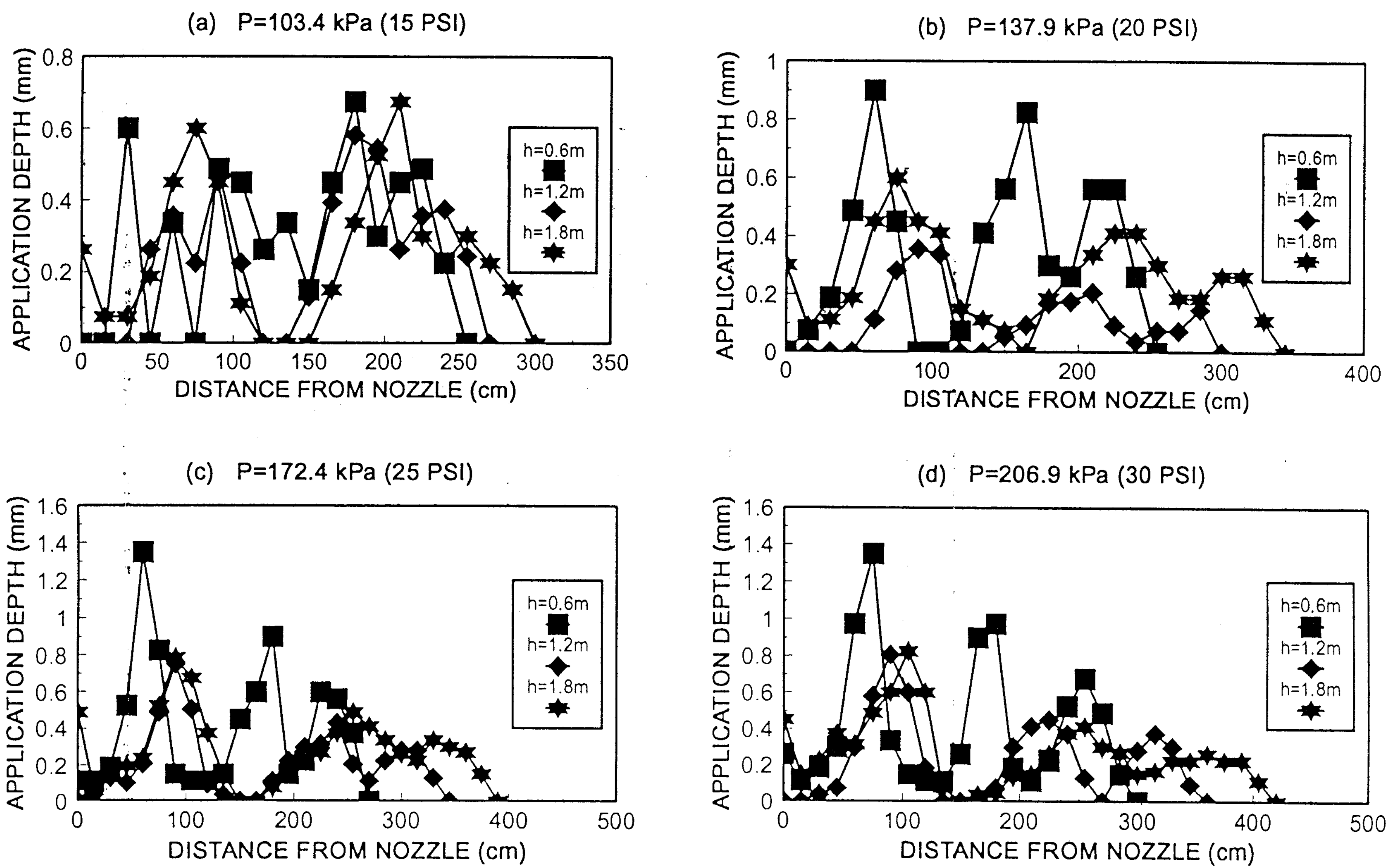

Fig. 3. Application pattern of the DAN7000 microsprinkler with a Green 12 Jet spreader.

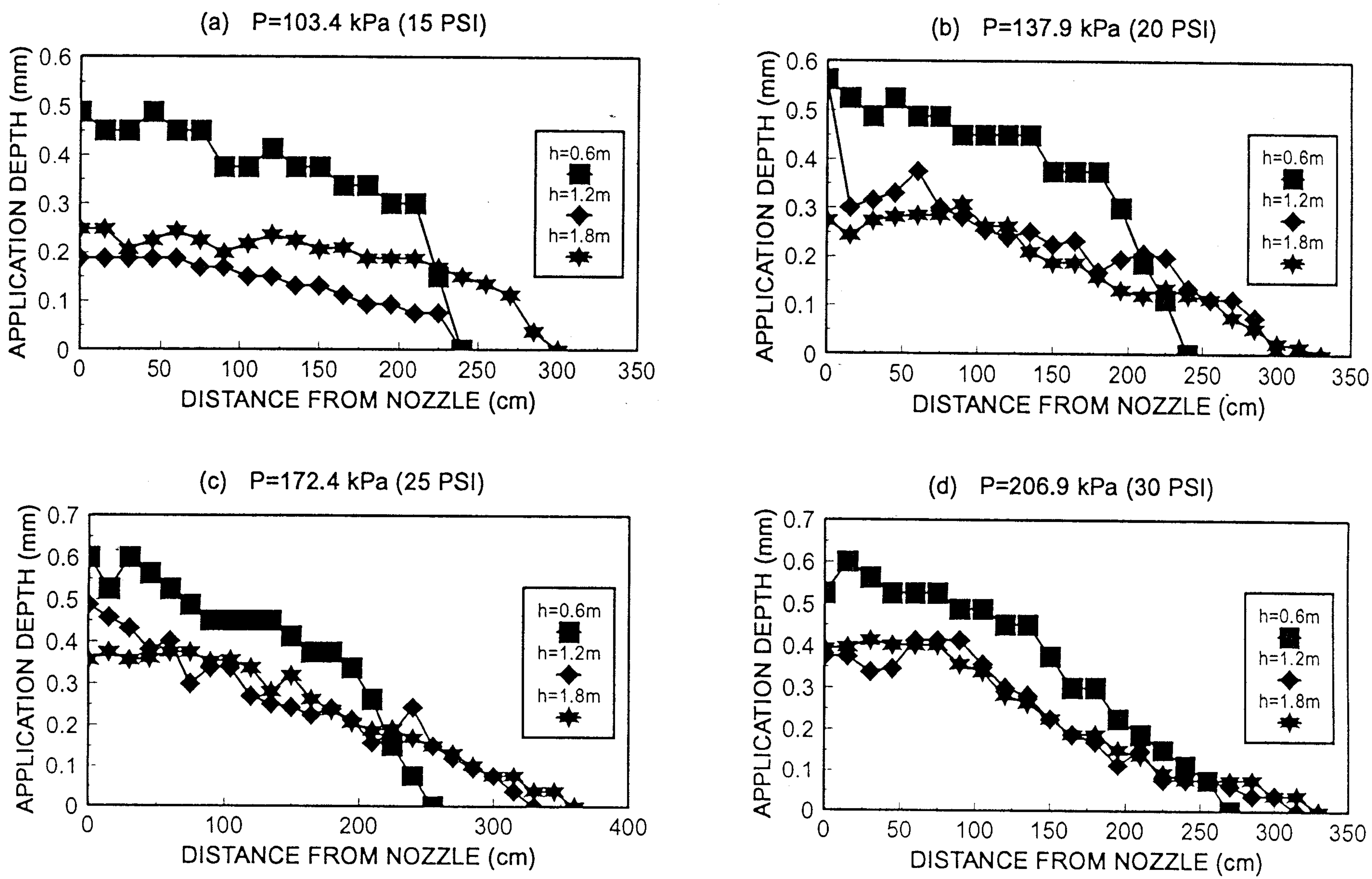

Fig.4. Application pattern of the DAN8000 microsprinkler with a Green Kiwi spinner.

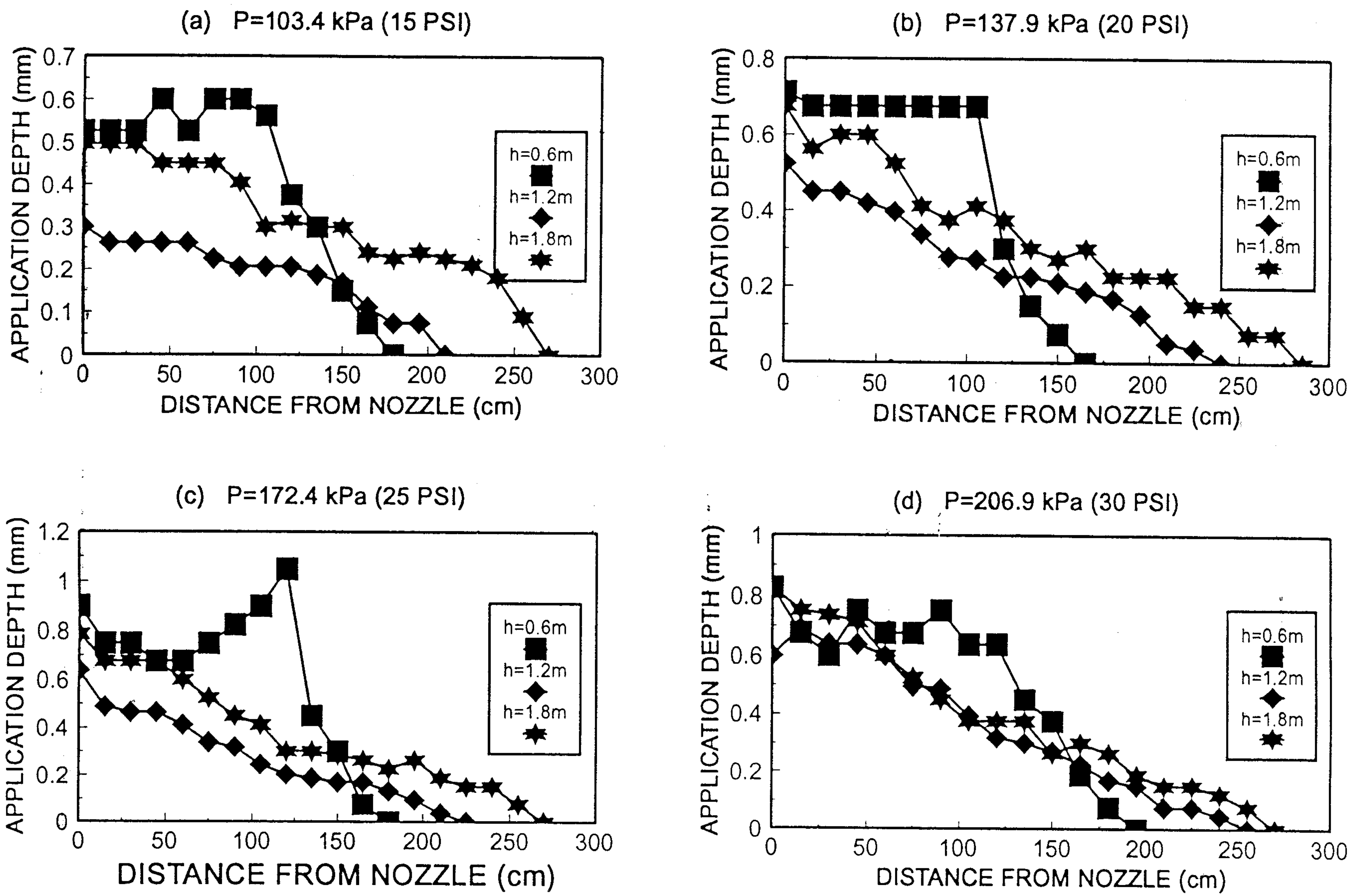

Fig. 5. Application pattern of the DAN8000 microsprinkler with a Black Round spinner.

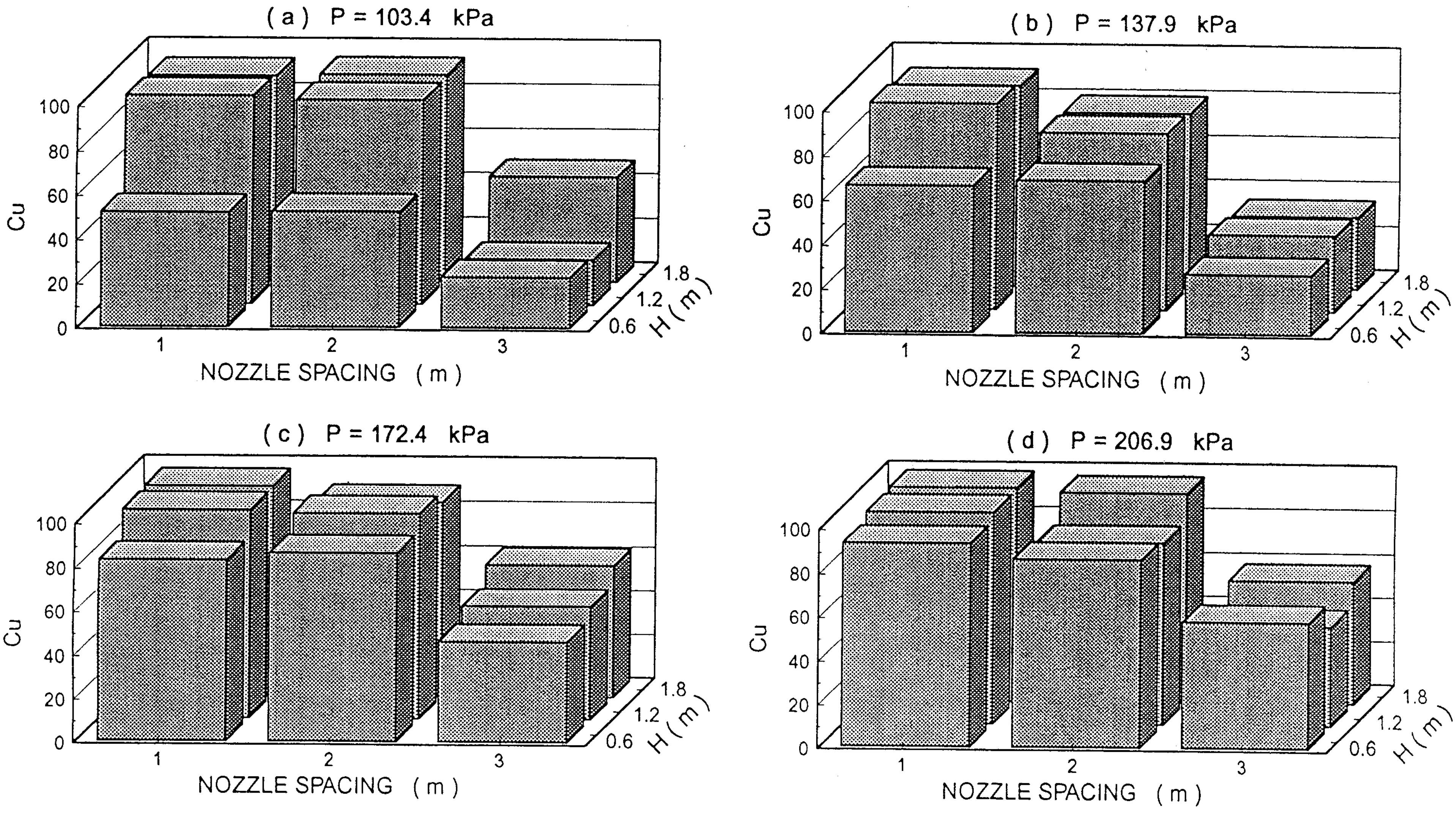

Fig. 6. Application uniformity of the DAN7000 microsprinkler with a Yellow Flat spreader.

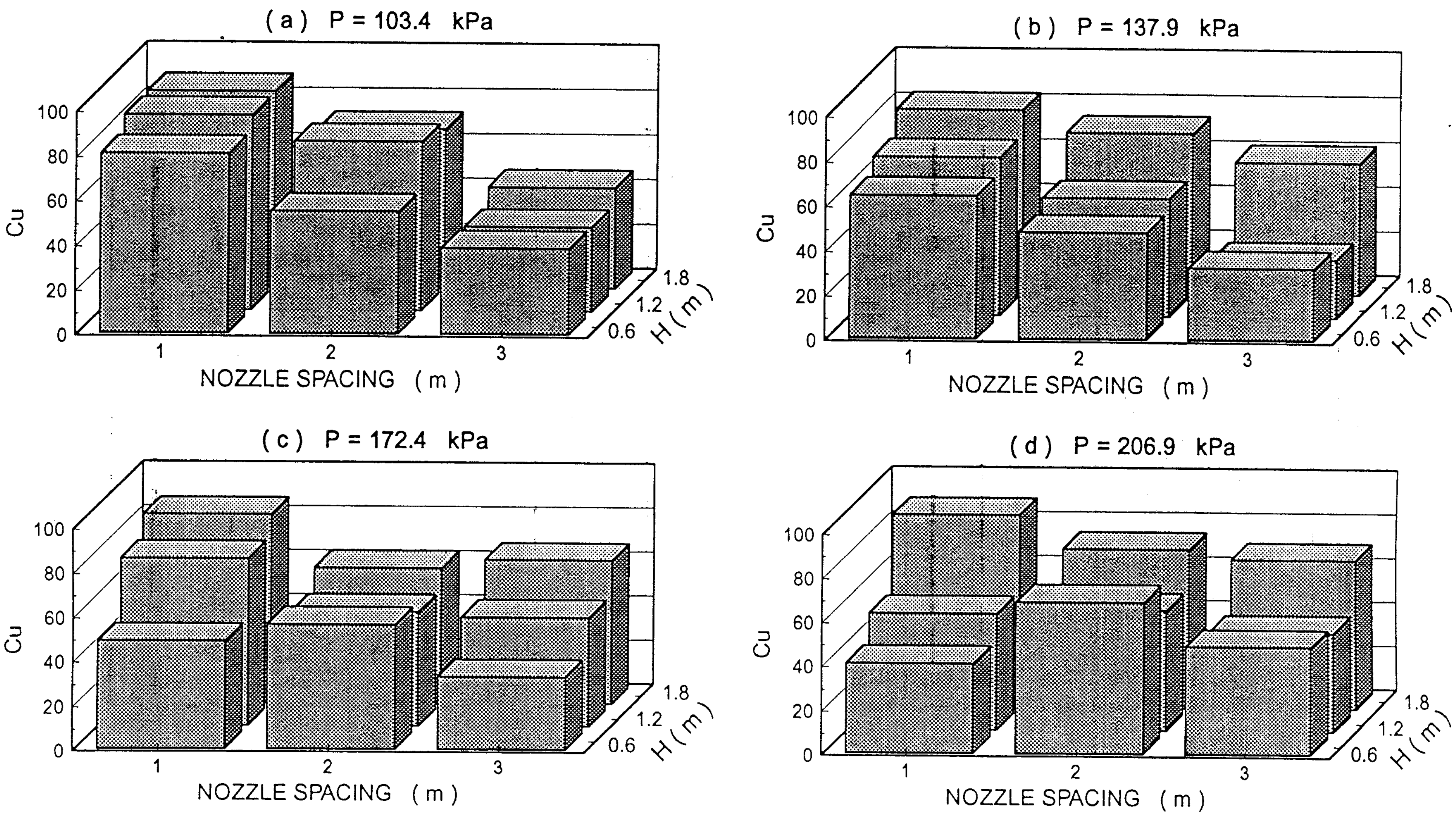

Fig. 7. Application uniformity of the DAN7000 microsprinkler with a Green 12 Jet spreader.

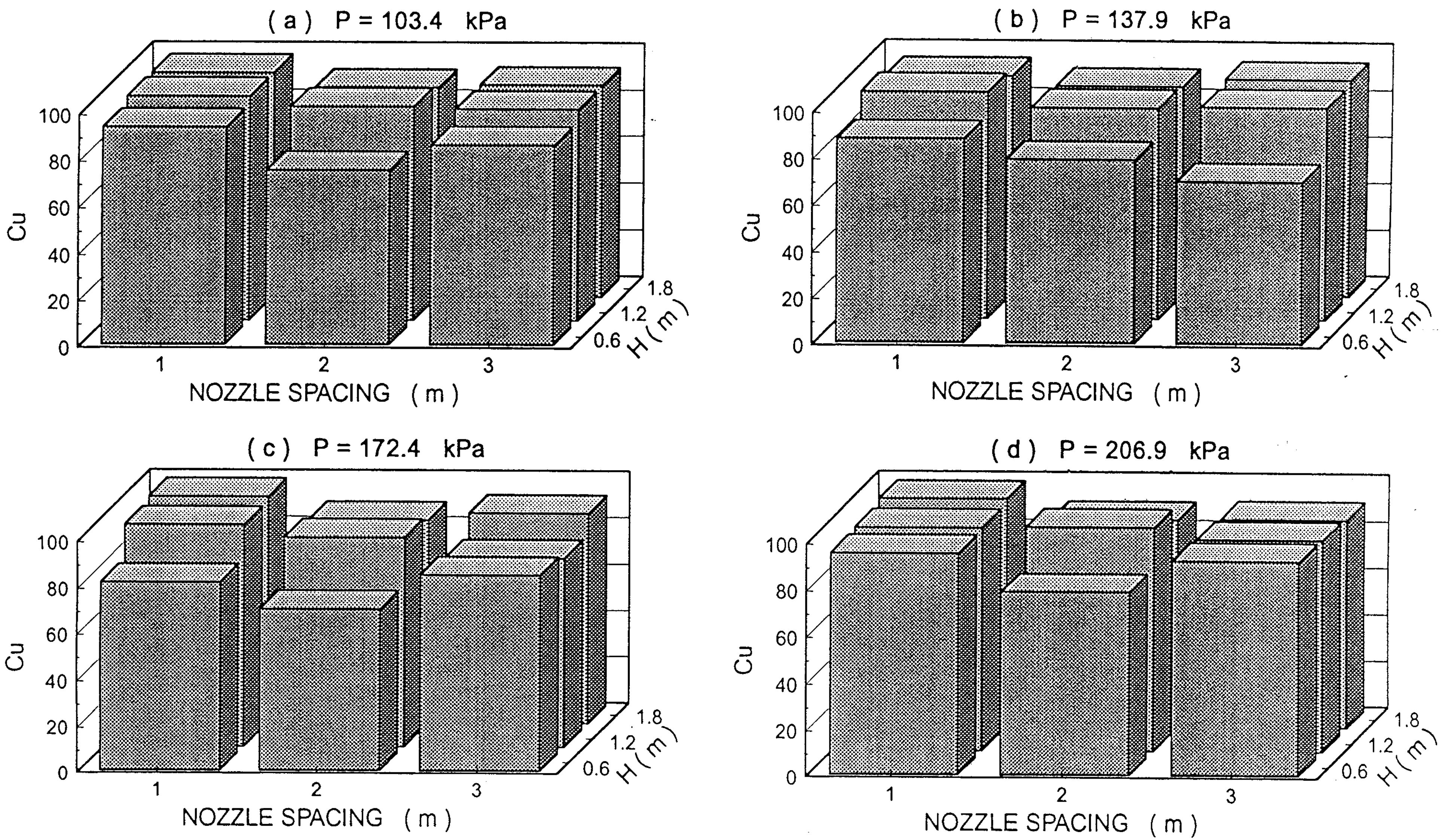

Fig. 8. Application uniformity of the DAN8000 microsprinkler with a Black Round spinner.

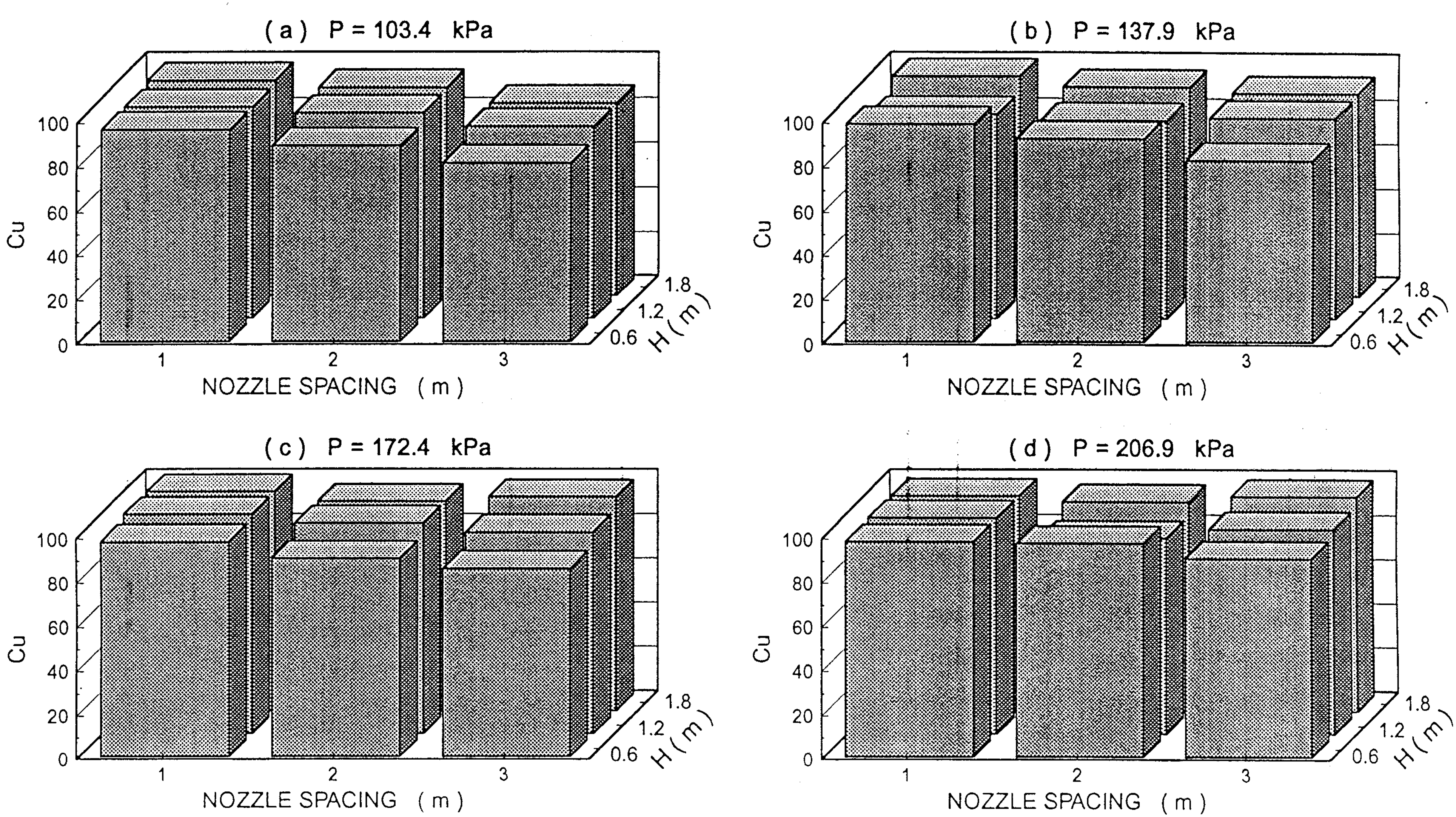

Fig. 9. Application uniformity of the DAN8000 microsprinkler with a Green Kiwi spinner.