THE EFFECT OF BOOM LEVELING ON SPRAY DISPERSION

Travis Burgers $^{1,2}$, Miguel Bustamante $^3$, Juan F. Vivanco $^3$

$^1$ Raven Industries, Sioux Falls, SD
$^2$ Department of Mechanical Engineering, South Dakota State University
$^3$ Universidad Adolfo Ibáñez, Viña del Mar, Chile

2023-02-07, SDSU Data Science Symposium
Agricultural sprayers

- commonly used in agriculture to disperse herbicides, pesticides and fertilizers
- generally consist of a centrally-located, self-propelled tractor and two boom wings
  - total sprayer width up to 48 m (158 ft)
- have numerous nozzles over the length of the boom
  - commonly 51-cm (20-in) spacing
AUTOMATIC BOOM HEIGHT LEVELING

- Automatic boom height systems reduce the variability in boom height
- Problems if boom is too low
  - Uneven spray dispersion can occur
    - Streaking: a complete lack of application can occur near severe overapplication
    - up to six times the target rate (Lardoux et al. 2007, Clijmans et al. 2000)
  - Weeds can develop resistance to herbicides when they receive sublethal doses (Tehranchian et al. 2017)

Clijmans et al. 2000
COMPARISON OF BOOM LEVELING SYSTEMS

- JD R4045
  - JD BoomTrac Pro (BT) versus Raven AutoBoom XRT
- RoGator 1100C
  - Norac UC5 Passive Roll versus Raven AutoBoom XRT
- 3 replicates x 3 speeds x 3 courses for each boom leveling system (Burgers et al. 2021)
BOOM HEIGHTS OVER THE WATERWAY AT 26 KPH (16 MPH)
ALL MEASURED WITH XRT SENSORS

Burgers et al. 2021
XRT IS LESS VARIABLE AND KEEPS BOOM CLOSER TO TARGET

- On all terrains at all speeds
  - XRT is less variable than BT and UC5
  - XRT keeps the boom closer to target than BT and UC5
IMPLICATIONS: BOOM HEIGHT AFFECTS SPRAY DISPERSION

(a) 50 cm
(b) 40 cm
(c) 25 cm
(d) 8 cm

16.9 m boom (55 ft)

0 deg
0.36 deg
0.90 deg
1.5 deg

50 cm
50 cm
50 cm
50 cm

Burgers et al. 2021

Raises question: how does boom leveling affect the spray coverage map?
Spray coverage can be measured with water sensitive paper
- Cards are 2 x 3 in (5 x 8 cm)
- Sheets are 9.5 x 11.75 in (24 x 30 cm)

Expensive
- $1–2 per 2 x 3 in card

Requires post-processing to quantify results

Not practical over a large area

gemplers.com

Ajay Sharda, KSU
HYPOTHESIS

- **Limitation**: only have the *implication* that boom leveling improves consistency of spray dispersion

- **Objective**: create a computational model
  - Inputs: boom heights and sprayer position in time
  - Output: spray coverage maps

- **Hypothesis**: automatic boom height leveling systems that control height better will have more consistent spray coverage
MEASURED SPRAY DISTRIBUTION FROM ONE NOZZLE

- Sprayed water from a flat fan nozzle at 20 in (50 cm) height
- Caught water in cups over a surface
- Weighed cup and calculated volume of water in each cup
- Calculated flow rate over surface

Jeff Doom, SDSU; Chapman and Doom (2021)
Flow rate is inversely proportional to square of distance

- Inverse square law – flux is inversely proportional to the square of distance

- \( q_r = q_{r_0} \frac{r_0^2}{r^2} \)
  - \( q_{r_0} \) is the measured flow rate at distance \( r_0 \)
  - \( q_r \) is the calculated flow rate at distance \( r \)
SPRAY DISTRIBUTION FROM ONE NOZZLE DUE TO ANGLED BOOM

- Boom (nozzle) angle affects the spray distribution

\[ \alpha = 0 \]
\[ \alpha = 0.1 \text{ rad (5.7 deg)} \]
\[ \alpha = -0.1 \text{ rad (-5.7 deg)} \]
SUPERPOSITION OF SPRAY DISPERSION FROM MULTIPLE NOZZLES

- Applied superposition to multiple nozzles to calculate flow rate over coverage area
SPRAY DISTRIBUTION FROM MULTIPLE NOZZLES DUE TO ANGLED BOOM

$\alpha = 0$

$\alpha = 0.01 \text{ rad (0.57 deg)}$
SPRAY DISTRIBUTION DUE TO MEASURED BOOM HEIGHTS
CALCULATED APPLICATION ERROR RELATIVE TO LEVEL BOOM

- Application Error = \( \frac{V_{\text{measured boom heights}} - V_{\text{level boom}}}{V_{\text{level boom}}} \)

- \( V_{\text{measured boom heights}} \) is volume from measured boom heights
- \( V_{\text{level boom}} \) is volume from level boom
  - Same course
COVERAGE MAPS: APPLICATION ERROR RELATIVE TO LEVEL BOOM

R4045, BT

R4045, XRT
RESULTS: COMPARISON OF APPLICATION ERROR FOR 3 SYSTEMS
CONCLUSIONS AND NEXT STEPS

- Computational model effectively calculates coverage maps from boom heights and sprayer position
- Model can calculate application error relative to level boom
- Very preliminary result implies AutoBoom XRT improves spray dispersion coverage
  - Only one run from each system
  - Only one speed
- Next steps
  - Analyze more runs
  - Make a more thorough comparison between automatic boom leveling systems
QUESTIONS/DISCUSSION

- Acknowledgement (single nozzle spray pattern)
  - Dr. Jeff Doom, SDSU

- Connect
  - Travis Burgers, Raven Industries
  - travis.burgers@ravenind.com