

8-2016

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Siebe, Anna and Luck, Joe D., "Height and Pressure Test for Improving Spray Application" (2016). *UCARE Research Products*. 129.
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Height and Pressure Test for Improving Spray Application

Anna V. Siebe, Undergraduate Student and Joe D. Luck, Professor

Abstract

Pesticide application in agricultural fields affects a little over a million acres each year (USDA 2012). Current spray application equipment can automatically adjust nozzle flow rates in reaction to speed changes to maintain consistent application rates across the field. Uniform distribution of pesticides from the spray boom is critical to ensure proper crop care while minimizing negative environmental effects. Boom pressure and height are two primary factors that affect proper spray uniformity; however information on the combined effects of these factors are limited. The goal of this study was to provide end users with quantified data regarding the effects of combined nozzle pressure and height variability on spray uniformity for three common spray nozzles. Specific objectives of this project were to 1) determine a suitable operating envelope (i.e., nozzle pressure and height) to meet current performance standards for the nozzles tests, 2) determine errors between theoretical spray distributions (from nozzle manufacturer flow and spacing data) to laboratory patternator data collected at different nozzle pressures, and 3) compare nozzle distribution errors (theoretical versus patternator data) with coefficient of variation (CV), a current spray uniformity performance metric. A laboratory patternator was used to collect nozzle distribution in 25 mm increments across the spray pattern while varying height and pressure for the spray nozzles tested. The operating envelope for different combinations of pressure and height was considered acceptable if the CV values were less than 10%. CV values were compared to root mean squared error (RMSE) for the AIXR 11003 nozzles operated at a height of 51 cm and four operating pressures to evaluate potential differences when accuracy is considered (i.e., RMSE). In some configurations the data exceeded 10% CV resulting in a more constricted operating envelope for each individual nozzle type. The CV values show more variance versus RMSE values. For the AIXR11003, as pressure increased the RMSE decreased in value, meaning the experimental pattern became closer to the ideal pattern as pressure increased. The CV values decreased as pressure increased until a threshold is reached; CV values focus on precision but not accuracy, showing the spray pattern was consistent but not necessarily accurate, indicating the CV disregards the theoretical values and does not indicate error in the values. Thus accuracy of spray pattern distribution may not be considered in the manufacturer's nozzle report.

Goals/Objectives

The goal of this study was to provide evaluated data supplying the effects of joined nozzle pressure and height changeability on spray uniformity for three common TeeJet spray nozzles. Specific objectives were to:

1. Determine a sufficient performing envelope to meet current performance standards for the nozzles tested
2. Determine errors between theoretical spray distribution to laboratory patternator data collected at different nozzle pressures
3. Compare nozzle distribution errors with CV, a current spray uniformity performance metric

Materials and Methods

A laboratory spray application simulator and patternator collection system were used to conduct experiments (Figures 1 and 2). Details on the operational components of the table were outlined by Luck et al. (2016).

Lateral nozzle flow rates were collected across the patternator in 25.4 mm increments. Each of the 30 collection tubes had a volume of 166.1 ml; the volume was divided by collection fill times as calculated by the automated system to calculate nozzle flow rates.

An adjustable spray boom was mounted above the pattern collection system which allowed for adjustments of height for the nozzles being tested (Figure 2). Nozzles were spaced at 50.8 cm as per manufacturer suggestions.

Materials and Methods

Testing Protocols:

- Nozzles: AIXR11003, XR11003, and XR8003
- Pressures: 138, 276, 414, and 552 kPa
- Boom Height for 80° nozzles: 40.6, 45.7, 50.8, 70, 71.1, 76.2, and 86.4 cm
- Boom Height for 110° nozzles: 25.4, 35.6, 40.6, 45.7, 50.8, 60.9, and 71.1 cm

Analysis:

- Lateral flow distribution, standard deviation, and the coefficient of variation were calculated from the patternator data
- Percent error was calculated to compare the actual CV value and the ideal value found in the current manufacturer's performance data (Figure 3)

Equations:

$$\%Error = \frac{Experimental - Theoretical}{Theoretical} * 100$$

$$Lateral\ Flow\ Distribution = \frac{Volume}{Time}$$

$$Standard\ Deviation = \sqrt{\frac{\sum_{i=1}^K (q_i - \bar{q})^2}{K - 1}}$$

$$Coefficient\ of\ Variation = \frac{Standard\ Deviation}{Mean} * 100$$

$$Root\ Mean\ Square\ Error = \sqrt{\frac{\sum ((Experimental - Theoretical)^2)}{N}}$$



Figure 1: Laboratory Patternator System.



Figure 2: Laboratory Spray Application Simulator.

Results

Figure 4 shows the average CV values performed for each nozzle, pressure and height configurations. According to published research, acceptable CV values are less than 10%. Values above 10% are indicated in red in Figure 4.

Percent error was calculated between theoretical spray distribution and the distribution flow rate collected on the spray application simulator for the AIXR 11003 nozzles at a height of 50.8 cm. Figure 5 shows the pattern of distribution of flow rate if the spray application were an ideal uniformity (blue) across the boom using the capacity of one nozzle (Figure 3). The experimental flow rate was the closest to the theoretical at 552 kPa.

Theoretical calculations were determined for nozzle configurations in regards to nozzle degree and height while ignoring pressure to see when tubes were collecting spray.

AIXR11003 (50)	1.0	XC	0.68
	2.0	XC	0.96
	3.0	VC	1.18
	4.0	C	1.36
	5.0	C	1.52
	6.0	C	1.67

Figure 3: Pressure in bar, droplet size classification and flow rate L/min for AIXR 11003 nozzles from manufacturer data (TeeJet, n.d.)

AIXR11003		Average CV						
Pressure (kPa)	Height (cm)	Average CV						
		25.4	35.56	40.64	45.72	50.8	60.96	71.12
138	No Data	20.61%	23.14%	30.40%	28.80%	28.29%	17.76%	
276	27.76%	10.65%	13.32%	12.37%	9.20%	6.52%	6.47%	
414	24.11%	8.68%	8.03%	5.02%	4.96%	5.94%	6.50%	
552	26.78%	7.09%	4.57%	3.35%	4.74%	5.18%	5.07%	

XR11003		Average CV						
Pressure (kPa)	Height (cm)	Average CV						
		25.4	35.56	40.64	45.72	50.8	60.96	71.12
138	20.32%	8.16%	8.07%	7.88%	7.05%	4.66%	6.21%	
276	17.63%	15.24%	8.82%	8.06%	4.25%	7.07%	9.24%	
414	12.27%	9.53%	7.83%	6.22%	6.20%	7.88%	9.00%	
552	15.56%	8.56%	6.50%	6.50%	5.63%	6.71%	7.61%	

XR8003		Average CV						
Pressure (kPa)	Height (cm)	Average CV						
		40.64	45.72	50.8	60.69	71.12	76.2	86.36
138	17.80%	9.75%	10.10%	10.10%	9.70%	5.97%	4.42%	4.49%
276	4.86%	7.31%	10.45%	6.00%	5.07%	4.14%	3.79%	
414	4.96%	6.61%	6.51%	4.71%	4.52%	4.42%	3.51%	
552	5.14%	6.77%	6.15%	4.58%	4.21%	4.66%	5.64%	

Figure 4: Average CV values for the TeeJet AIXR11003, XR11003, and XR8003 at pressure and height settings.

Percent Error Results

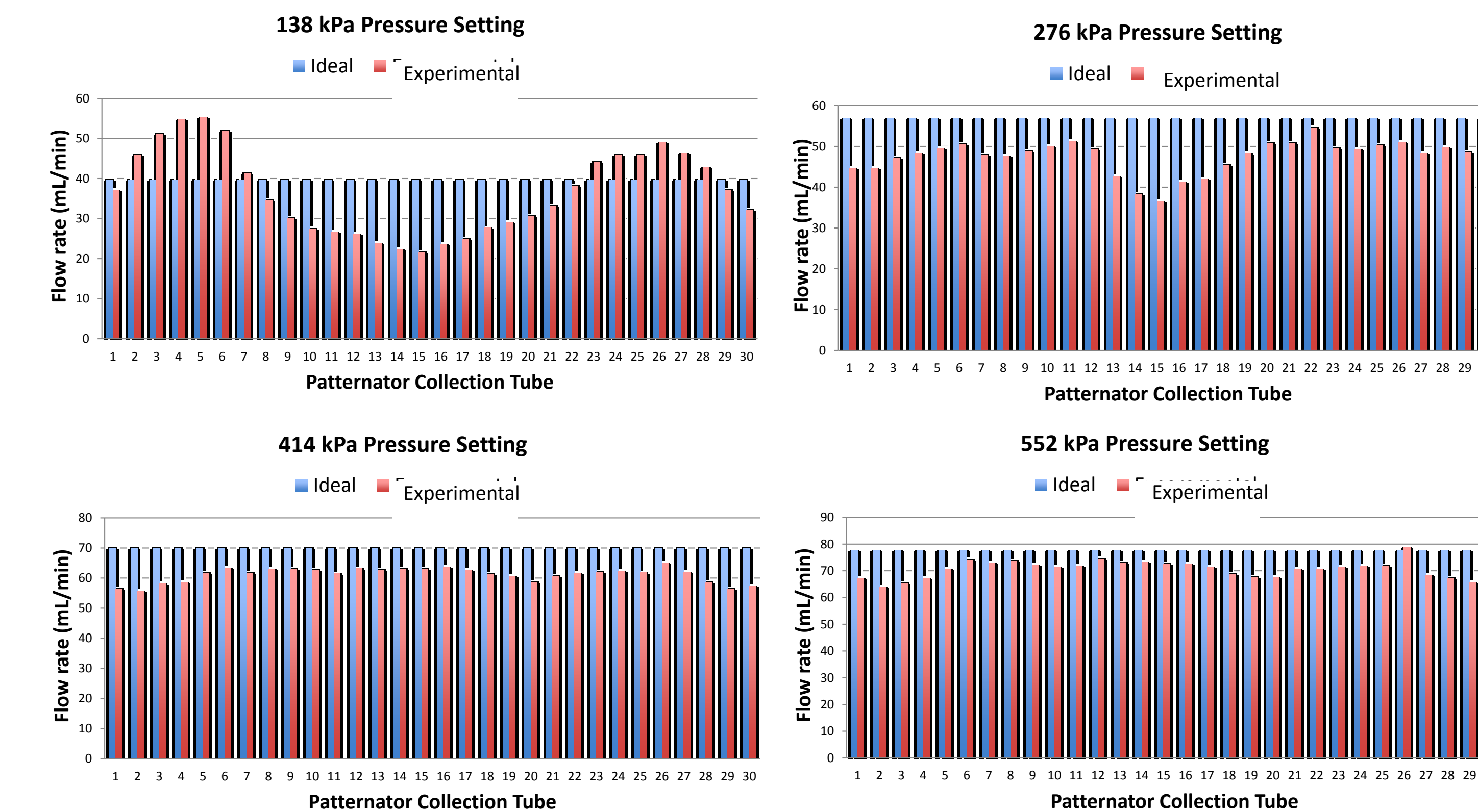


Figure 5: Average patternator collection tube experimental and theoretical flow rates for AIXR11003 nozzles operated at 138, 276, 414, and 552 kPa pressure settings.

Table 1: Comparison of Average CV values to Average RMSE values for AIXR11003.

Pressure (kPa)	Average CV (%)	Average RMSE (mL/min)
138	28.8	10.8
276	9.2	10.2
414	4.1	9.3
552	4.74	7.9

Table 1 shows the comparison of the AIXR11003 nozzle's average CV value to the average RMSE value. As shown with the CV value, the AIXR11003 nozzle achieves the best CV value at 414 kPa. While looking at the RMSE value it is best at 552 kPa meaning the experimental data was closest to the theoretical value at that pressure.

Conclusion

- A wide range of pressure and height settings would have created a distribution that would have been considered acceptable (i.e., CV < 10%) for the XR 8003 nozzles.
- Heights above 25.4 cm should be maintained to allow for acceptable spray patterns at pressures from 138 kPa to 552 kPa for the XR 11003 nozzle.
- Care should be taken when using AIXR 11003 nozzles with regard to pressure and height. Operation of nozzles below 276 kPa could result in poor CVs unless optimal heights (50.8 cm) were maintained. At higher pressures (> 414 kPa) CVs below 10% were recorded.
- A detailed comparison of CV versus RMSE for the AIXR 11003 nozzles showed that while CV values might be considered acceptable, RMSE values exceeded 10 mL/min (greater than 10% of the average flow rate distribution) which could be a problem. In this case, further research into the relationship between CVs and flow rate errors may be warranted.

References

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