1-1-1982

Field Evaluation of Calibration Accuracy for Pesticide Application Equipment

A. R. Rider
University of Nebraska at Lincoln

Elbert C. Dickey
University of Nebraska at Lincoln, edickey1@unl.edu

Field Evaluation of Calibration Accuracy for Pesticide Application Equipment

A. R. Rider, E. C. Dickey
MEMBER ASAE MEMBER ASAE

ABSTRACT

A 1979 field survey was conducted in Nebraska and western Iowa of 152 private and commercial pesticide applicators. The survey showed that only one out of every four cooperators were applying pesticides within 5 percent of their estimated application rate. Incorrect calibration accounted for the greatest amount of application errors and ranged from nearly 60 percent underapplication to more than 90 percent overapplication. Uniformity of the application was also in error. The coefficient of variation among nozzles for liquid applicators averaged 21.9 percent whereas granular applicators averaged 4.7 percent among boxes. The survey also showed that the most common method of calibration was the Known Area method, but no statistical relationship between this method and accurate applications was measured.

INTRODUCTION

Applying pesticides at the correct rate is essential to acquire satisfactory pest control without damaging the crop. Obtaining the proper rate requires accurate calibration of application equipment which is largely dependent on the competence and reliability of the person applying the pesticides. Even though certified pesticide applicators receive training in equipment calibration, there is no assurance that chemicals are applied accurately. The Guide for Commercial Applicators (USEPA and USDA, 1975), states that the application error should be within 5 percent of the recommended or desired rate. However, only limited documentation is available to assess actual application rates. A study conducted in England (ADAS, 1976) showed that almost half of the cooperators surveyed had recorded application errors of more than 10 percent from their desired rate.

Randomly selected operators of pesticide application equipment were surveyed in Nebraska and western Iowa for this study. A total of 152 private and commercial applicators cooperated in the survey which was conducted during the spring and summer of 1979. A variety of equipment and crop conditions were encountered.

Article was submitted for publication in July 1981; reviewed and approved for publication by the Power and Machinery Division of ASAE in October 1981.

Published as Paper No. 6126, Journal Series, Nebraska Agricultural Experiment Station.

The authors are: ALLEN R. RIDER, Engineer, R & D Group, Sperry New Holland, New Holland, PA (formerly Extension Agricultural Engineer, Agricultural Engineering Dept., University of Nebraska, Lincoln); and ELBERT C. DICKEY, Extension Agricultural Engineer, Agricultural Engineering Dept., University of Nebraska, Lincoln.

Acknowledgments: Appreciation is given to Paul Jasa, Robert Pharris and Pat Lee for data collection and analysis.

PROCEDURE

Calibration Techniques of Cooperators

This study was designed to evaluate the calibration methods used by private and commercial applications and to measure actual field application rates of pesticides.

Calibration methods used by liquid and granular applicators included:

1 Known Area
2 Operator Manual Recommendation
3 Field Adjusted
4 Caught Output
5 All adjustments same as last year

With the Known Area method, the amount of pesticide or tank mix applied to a measured area was determined and the application rate was calculated. Equipment was readjusted as necessary to achieve the desired application rate. Operator Manual Recommendations used as a calibration method required only that pesticide application equipment be set according to manufacturer's suggested guidelines and specifications. The Field Adjusted method was a refinement of the Operator Manual method and required that pesticide application equipment be set according to manufacturer's specifications with adjustments being made as necessary by using known field sizes and the amount of material applied. Catching the output was a stationary method for calibrating liquid applicators and consisted of measuring the output for a specified time. For granular applicators, the output was collected for a given number of drive wheel revolutions at equivalent field speed or a measured travel distance using the desired travel speed. Calculations were then made to obtain the application rate and adjustments were made as necessary.

Survey Data Acquisition

Observations were made and test data were collected by technicians on site during calibration and application. During calibration, whenever possible, appropriate data were simultaneously collected with the cooperator. However, there was no collaboration with the farmers which would influence their calibration procedure. Measurements taken for a Known Area calibration procedure were spray swath width, swath length, volume of spray delivered, boom pressure and ground speed. Data collected for a stationary calibration procedure were nozzle delivery rates and corresponding boom pressure.

After calibration, computations were made to determine the amount of chemical to be mixed with the carrier. Spray tank volume was determined and the amount of chemical added per tankful was recorded. The common chemical and product names with the percentage of active ingredient were also recorded.

Upon completion of calibration and mixing, spray was applied to the field following the cooperator's normal

  0001-2351/82/2502-0258$02.00

operating procedures. Data collected were the time required for application, volume of spray applied and total area sprayed. To determine uniformity of application, output from individual nozzles was measured and compared to the mean application rate for the machine. The actual application rate of pesticides was then compared with the cooperator's expected application rate. The following equation was used to calculate the application error for comparison of the cooperator's estimated rate and actual measured rate:

$$\text{Application Error \%} = \frac{\text{Measured Rate} - \text{Estimated Rate}}{\text{Estimated Rate}} \times 100$$

The survey procedure for liquid applicators was modified as necessary for granular applicators. The application error and uniformity of application was calculated using methods similar to that for liquid pesticide applications.

RESULTS AND DISCUSSION

Liquid Applicators

Liquid pesticide application errors can result from incorrect calibration, incorrect mixing ratio of the pesticide with carrier (generally water), or a combination of both. Eighty-five percent of the cooperators observed had a calibration and/or mixing error in excess of 5 percent (Table 1). Using a 5 percent error as an acceptable guideline, 47.3 percent of the cooperators had a calibration error and 7.1 percent had a mixing error. However, an additional 30.6 percent of the cooperators had both a calibration and mixing error.

The magnitude of calibration errors ranged from nearly 60 percent underapplication to more than 80 percent overapplication (Fig. 1). The mean calibration error for all liquid applicators was +0.2 percent with a standard deviation of 29.1 percent from the estimated application rate. Only 22.1 percent or less than one out of every four cooperators had sufficient calibration accuracy to apply a tank mix within 5 percent of the intended application rate. However, over 50 percent of the cooperators surveyed were within 20 percent of their desired rate. Of the 95 liquid applicators, 41.1 percent were underapplying tank mixes with a mean underapplication rate of 25.5 percent. Approximately 37 percent were overapplying tank mixes with the mean overapplication rate exceeding the estimated application rate by 29.2 percent.

Although incorrect calibration is primarily responsible for tank mix application errors, both calibration and mixing errors influence the actual chemical application rate. The actual mean chemical rate for all liquid applicators was 2.8 percent below the estimated chemical rate with a standard deviation of 26.2 percent. Fig. 2 shows the percentage distribution of chemical application errors which ranged from approximately 60 percent underapplication to 80 percent overapplication.

Of the liquid pesticide applicators observed, 24.1 percent were within 5 percent of the desired chemical application rate. However, over one-half of these applicators applied actual chemicals within 15 percent of the estimated rate. This improved application accuracy compared with calibration accuracy was possible because the flow rate could be adjusted slightly to offset mixing errors, thus achieving the desired chemical application rate. Forty-four percent of the cooperators underapplied chemicals at a mean underapplication rate of 24.8 percent. Comparatively, nearly 32 percent overapplied chemicals at a mean rate of 25.2 percent.

TABLE 1. TYPES OF LIQUID APPLICATION ERRORS CORRELATED WITH COOPERATORS MAKING THOSE ERRORS.

Error	Cooperators	
	No.*	%
Calibration	65	47.3
Mixing	10	7.1
Both	42	30.6
None	21	15.0

*Total of 138 was the result of several of the 95 cooperators surveyed mixing more than one chemical per tank.

Granular Applicators

Reported errors in application of granular pesticides are caused by inadequate calibration since no equipment failures or plugged distribution tubes were observed. Calibration errors for granular pesticide application ranged from nearly 35 percent underapplication to more than 90 percent overapplication (Fig. 3). The mean granular pesticide application rate was 8.7 percent over the estimated rate with a standard deviation of 29 percent.

Of the 38 cooperators applying granular pesticides, only 23.7 percent were applying granules within 5 percent of the desired rate. However, 50 percent of the cooperators were applying granules within 15 percent of the

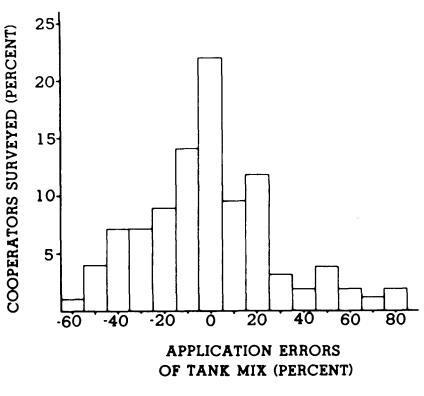

FIG. 1 Percentage distribution of application errors for tank mixes. These errors are mainly the result of improper calibration.

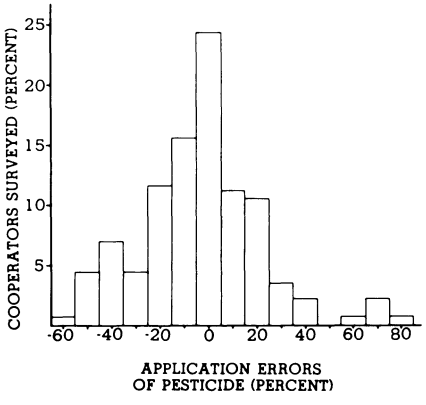

FIG. 2 Percentage distribution of application errors for actual liquid chemicals. These errors are the result of improper mixing, calibration or a combination of both.

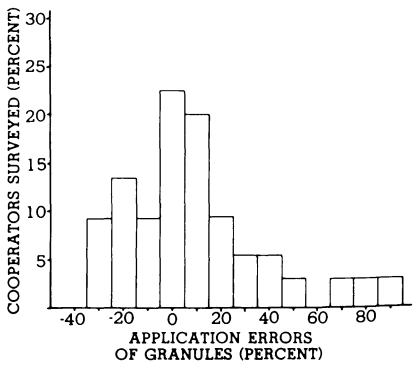

FIG. 3 Percentage distribution of application errors for granular pesticides.

intended rate. Almost 30 percent of the granular applicators were underapplying with a mean underapplication rate of 20.3 percent. Nearly 50 percent of the granular applicators exceeded the estimated rate with a mean overapplication of 30.6 percent.

Uniformity of Application

Uniformity of application in addition to actual application rate was measured on 18 liquid and 36 granular applicators. The coefficient of variation among nozzles for liquid applicators averaged 21.9 percent whereas the coefficient of variation averaged 4.7 percent among boxes for granular applicators. The maximum coefficient of variation was 65.2 percent for liquid applicators and 19.1 percent for granular applicators. Specific data regarding the coefficient of variation are shown in Table 2. If a 5 percent coefficient of variation among nozzles is an acceptable uniformity of application, then only 11.1 percent of the liquid applicators had acceptable uniformities. However, 69.4 percent of the granular applicators had acceptable uniformity of applications because the operator could easily observe if the boxes were applying different rates and make appropriate field adjustments. Comparatively, an operator could not normally observe differences in individual nozzle outputs for liquid applicators.

Correlations between the coefficient of variation for uniformity of application and application errors were conducted to determine if a relationship existed between application rates and uniformity of application. At the 5 percent significance level, no correlations were obtained indicating that applicators having acceptable application rates do not necessarily have uniform applications.

Calibration Methods

The Known Area method of calibration was the most common technique and was used by 42.4 percent of the liquid cooperators and 36.1 percent of the granular cooperators (Table 3). Calibrating with the use of the Operator Manual recommendations was done by 30.4 percent and 22.2 percent of the liquid and granular cooperators, respectively. Although less than 10 percent of the liquid cooperators used the Field Adjusted and Caught Output techniques, more than 16 percent of the granular cooperators used both. Less than 10 percent of the cooperators left adjustments the same as those in the previous year.

Table 3 also shows the percentage of applicators using each calibration method that were within 5 percent of their estimated application rate. More than 42 percent of the liquid cooperators using the Field Adjusted calibration method were within 5 percent of their desired application rate. Similarly, 37.5 percent of the cooperators who set granular application equipment according to Operator Manual recommendations were within 5 percent of their estimated rate. However, at the 5 percent significance level, there were no differences detected among the calibration methods and pesticide application errors.

CONCLUSIONS

Only one out of four pesticide applications were applied within 5 percent of the intended rate. The major source of application errors was incorrect calibration. For the granular pesticide applications, unsatisfactory calibration was determined to occur with 76.3 percent of the applicators observed. Calibration errors were also detected in 77.9 percent of the liquid pesticide applications. Tank mix errors were detected in 37.7 percent of the liquid pesticide applications.

Uniformity of application in addition to application errors was of concern especially for liquid applicators. The coefficient of variation among nozzles for liquid applicators averages 21.9 percent whereas granular applicators averaged 4.7 percent among boxes. Only 11.1 percent of the liquid applicators had a coefficient of variation of 5 percent or less. However, 69.4 percent of the granular applicators had acceptable uniformity of application. No significant relationship between application error and uniformity of application was measured.

The most common method of calibration used was the Known Area method. No statistical differences between calibration methods and pesticide application errors were detected. However, the most successful calibration method, based on observed trends, was to adjust equipment following operator manual recommendations and to make appropriate field adjustments as necessary.

References

1 Agricultural Development and Advisory Service. 1976. The utilization and performance of field crop sprayers. Ministry of Agriculture, Fisheries and Food. Middlesex, England. Farm Mechanization Studies No. 29.

2 United States Environmental Protection Agency and United States Department of Agriculture. 1975. Apply pesticides correctly — a guide for commercial applications. U.S. Government Printing Office.

TABLE 2. PERCENTAGE DISTRIBUTION OF THE COEFFICIENT OF VARIATION FOR UNIFORMITY OF APPLICATION AMONG NOZZLES OR BOXES ON INDIVIDUAL PESTICIDE APPLICATION EQUIPMENT.

Coefficient of variation*	Percent of pesticide applicators†	
%	Liquid	Granular
0-5	11.1	69.4
5-10	27.8	22.2
10-15	11.1	2.8
15-25	16.7	5.6
25-50	27.8	—
>50	5.5	—

*Coefficient of Variation = $\frac{\text{Standard deviation of individual outputs}}{\text{Mean application rate}}$

†18 sprayer applicators and 36 granular applicators

TABLE 3. CALIBRATION METHODS AND PERCENTAGE OF APPLICATORS WITHIN 5 PERCENT OF THE ESTIMATED APPLICATION RATE.

Calibration Method	Applicators Using Method		Applicators within each method that are 5% of estimated rate	
	Liquid %	Granular	Liquid %	Granular
Known area	42.4	36.1	15.4	15.4
Operator manual recommendations	30.4	22.2	28.6	37.5
Field adjusted	7.6	16.7	42.9	33.3
Caught Output	9.8	16.7	11.1	16.7
All adjustments same as previous year	9.8	8.3	33.3	33.3