EFFECTS OF LOWERING AERIAL SPRAY BOOM ON SPRAY DRIFT AND SWATH WIDTH

W. C. Hoffmann and H. H. Tom
USDA-ARS
-Areawide Pest Management Research Unit
College Station, TX

Abstract

Drift is one of the major concerns of today's aerial applicators. With the increasing encroachment of urban areas into agricultural lands and changing regulatory conditions, aerial applicators must use the latest technology to make every application as efficient as possible. A spray boom system for aircraft was designed, constructed and tested. The system lowers the spray boom by 0.45 m (1.5 ft) and moves forward by 0.37 m (1.2 ft) once the aircraft is in the air. The purpose of constructing the system was to increase the distance between the spray release point and the turbulence generated by the aircraft.

During in-wind swath analysis tests, the swath width was increased by 1.9 m, resulting in a 10.3% increase in swath width. A drift test was conducted to compare the drift from the spray system with the boom in the raised (original) versus lowered positions. There was 25.9 and 55.9% less deposition at 10 and 310 m, respectively, from the flightline with the boom lowered.

Introduction

Application equipment, operational variables, and meteorological conditions influence on- and off-target deposition and the overall effectiveness of an agrochemical application (Yates et al. 1974; Threadgill and Smith, 1975; Kirk et al., 1991; and Salyani and Cromwell, 1992). Droplet size and spray formulations have been found to significantly affect drift from aerial applications (Yates et al., 1976; and Bouse et al., 1990). Teske and Barry (1993) identified release height as the most influential parameter in terms of increasing in-canopy deposition and reducing drift. Lower release heights resulted in higher deposits at the target site and reduced drift. Franz et al. (1995) reported that aircraft flying at 1.8 m above the canopy created higher turbulence in a canopy but less spray deposition than an aircraft at 3.7 m. The increased turbulence at the site of deposition may have entrained the smaller droplets and prevented deposition at the target site. Zhu et al. (1996) found that collection efficiency of deposition targets decrease as turbulence intensities around the target increase. Researchers are increasingly using computer simulation to investigate the role of various application parameters on depositions and drift (Smith, 1970; Miller and Hadfield, 1988; Reichard et al., 1992; and Zhu et al., 1994). Through a better understanding of factors contributing to drift potential of an application, researchers can modify equipment and operational parameters to negate drift-causing factors.

A drop or lowering boom system for agricultural aircraft would decrease the amount of spray material captured in the vortices or turbulent wake of the aircraft. This system would allow droplets to reach their target with less air turbulence interference. In theory, the amount of off-target deposition from a spray application would also be decreased, which would be of great benefit to aerial applicators. Research efforts concerning the design, construction, and evaluation of such a system are discussed. The new boom placement system greatly increases the distance between the release point of the spray droplets and the turbulent air generated at the wingtips and from the trailing edge of the wing.

Objectives

1. Design and construct an aerial spray boom system to increase the distance between the spray release point and the trailing edge of the wing;
2. Evaluate the effect of the boom system on spray swath width and drift.

Materials and Methods

Boom Lowering System

The boom lowering system uses a conventional spray boom that is attached to a mechanism that lowers by 0.45 m (1.5 ft) and brings forward by 0.37 m (1.2 ft) the boom once the aircraft is in the air. The boom lowering mechanism consists of a flap motor, shaft, bearings, boom arms, and boom holders. The motor is an aircraft approved flap motor (Air Tractor, Olney, TX) with a 4-in linear displacement screw drive. An attachment assembly, that uses the screw drive displacement to exert torque on the shaft, causes rotation in the shaft. For emergency landings, a quick disconnect mechanism was designed into the system to allow the pilot to uncouple the shaft and motor in flight allowing the boom to be retracted into it's landing or raised position automatically, through wind forces and springs. The seven-piece shaft runs along the chord of the wings and is located below the boom attachment points that are present on the aircraft. A slip joint assembly on the shaft allows the shaft to shorten and lengthen as the wing flexes. The slip joint assembly consists of two pieces of square tubing each welded to an end of adjoining shaft pieces. One piece of the tubing was machined to fit tightly (0-0.02 mm tolerance) into the other, which allows torque to be transmitted along the shaft, while the joint can slip to avoid binding.

At the four attachment points on each wing, a drive arm is coupled to the shaft (Figure 1) and extends 0.78 m (31 in) to the trailing edge of the spray boom, which holds the boom in its original position when the system is raised.

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When the shaft is rotated, the arm pushes/pulls the boom through the desired motion. A support arm is attached between the leading edge of the spray boom and near the shaft so that as the boom moves between its raised and lowered position, it is held parallel to the airflow through a parallelogram-like assembly. Boom holders were designed to allow the two arms in the assembly to hold the boom while allowing the attachment point to rotate as the boom moved through the desired motion.

Swath Width Analysis

An Air Tractor 402B was flown across a monofilament swath analysis system, which provided a continuous sampling across the swath. The system used blue dye as a marker for the colorimetric assessment of the swath pattern. After the pattern was analyzed, software displayed the pattern and calculated the coefficient of variation (ASAE Standard # 386.7) so that effective swath width could be calculated.

The aircraft made one in-wind pass for each of four alternating replications with the boom in the raised and lowered position. Since the boom could be raised and lowered in flight, the test protocol was to make one pass with the boom raised, analyze the spray pattern, replenish the monofilament line, then make the next pass with the boom lowered. This was repeated four times. The spray solution was water, Triton X-100 at 0.1% v/v, and FD&C #1 blue dye at 20 g/L of water. The spray was turned on 100 m before crossing the monofilament line and turned off 100 m afterwards. The aircraft operation parameters were: speed - 58.1 m/s (130 mph); height - 3 m (10 ft); spray rate - 46.7 L/ha (5 gal/acre); nozzles – CP nozzles with an 0.125 orifice, 30° deflector, and 241 kPa (35 psi). The spray boom was setup to spray 65% of the wingspan.

Drift Study

An Air Tractor 402B aircraft with the same operational parameters as described in the Swath Width Analysis section was loaded with water, FD&C #1 blue dye at 10 g/L of water, Triton X-77 at 0.1% v/v, and Acid Yellow fluorescent dye at 5g/L of water. The blue dye was used by the swath analysis system and the fluorescent dye was used to measure drift on mylar cards placed 10 – 310 m downwind from the spray centerline (Figure 2). During each of the four, alternating raised and lowered boom replications, the aircraft made one W-E pass and one E-W pass while the wind was from the south. The spray was turned on 100 m before the S-N sampling line and continued for 100 m past the sampling line.

After a replication was completed, the monofilament line was brought in for swath analysis. The mylar cards (100 cm²) were placed in labeled Zip-loc bags and new cards put out. This process took less than 15 min/replication; therefore, the meteorological conditions were fairly constant for each set of raised and lowered boom replications. Samples were transported to the laboratory for quantification. Twenty ml of methanol were pipetted into each bag, the bags were agitated, and 6 ml of the effluent was poured into a cuvette. The cuvettes were then place into a spectrofluorophotometer (Shimadzu, Model RF5000U, Kyoto, Japan) with an excitation wavelength of 453 nm and an emission at 488 nm. The fluorometric readings were converted to μg of dye/cm².

Results and Discussion

In-wind Swath Analysis

The mean swath when the boom was raised was 18.2 m (59.7 ft) and 20.1 m (66.0 ft) when the boom was lowered. These values represent the maximum swath width where the coefficient of variation is less than 20%. The results represent a 10.3% increase in swath width. This increase translates into a significant increase in productivity or area covered during each spray pass. The increased swath width was likely a result a reduction of spray material becoming entrained in the wingtip vortices. This allowed more of the spray to deposit within the swath.

Drift Study

The increase in swath width for the lowered boom position was greater during the drift study than during the in-wind measurement. The mean swath width with the boom in the raised and lowered positions was 21.1 m (69.3 ft) and 24.8 m (81.3 ft), respectively. The 17.3% increase may be the result of decreased spray in the vortices as discussed in the previous section, lower spray release heights, and the influence of crosswind on swath width. The aircraft was flown so that the wheels were approximately 2 m above the ground during all tests. When the boom was lowered, the spray boom was 0.46 m (1.5 ft) lower and 0.37 m (1.2 ft) forward compared to the raised position. This lower release height may have resulted in less lateral displacement of the spray plume before the plume deposited on the ground.
There was 25.9 and 55.9% less mean deposition on the downwind targets at 10 and 310 m, respectively (Figure 3 and 4), with boom in the lowered position. Except at 20 and 40 m from the centerline of the spray, the downwind drift was less at each sampling site when the boom was in the lowered position. This pattern of deposition will allow applicators to be more confident that the spray is depositing in the field and not impacting off-target sites.

Conclusions

A system for lowering and bringing forward an aerial spray boom was designed, constructed, and evaluated. The drop boom system provided increased swath width and decreased off-target deposition. With the boom in the lowered position, swath width was increased by 10.6%. Off-target deposition was reduced by 25.9 and 55.9% at 10 and 310 m downwind, respectively, with the boom lowered. While the system increased the drag loading on the aircraft, a modification to the system is expected to greatly reduce the drag loading caused by the system.

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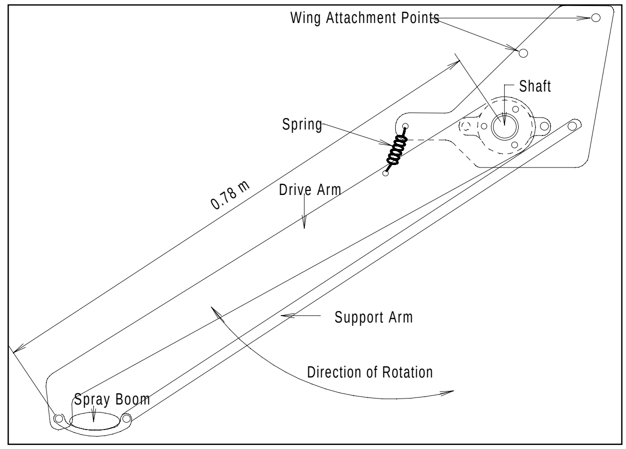

Figure 1. Boom hanger and lowering mechanism

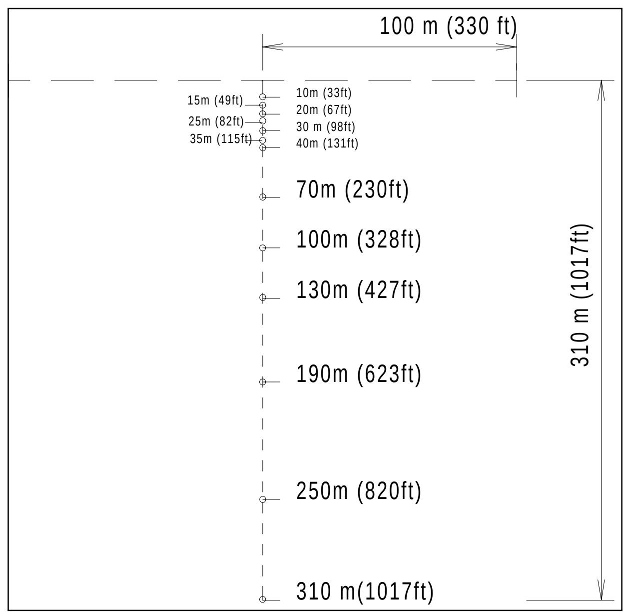

Figure 2. Drift test layout for drop boom system.

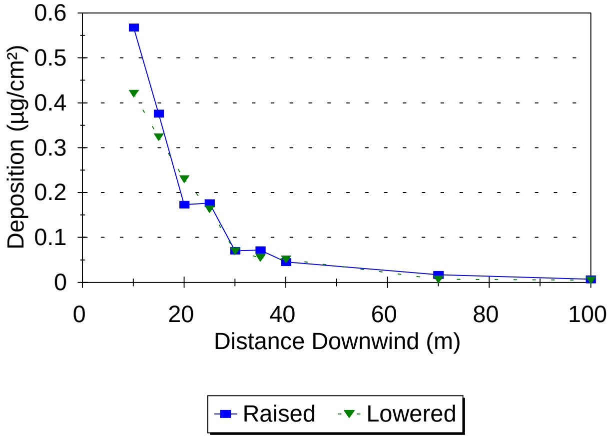

Figure 3. Downwind deposition from 10-100m from spray centerline

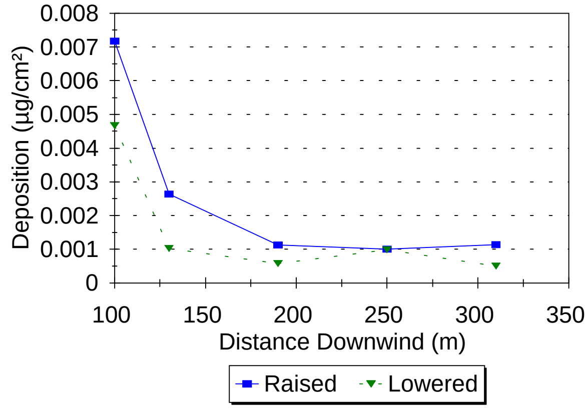

Figure 4. Downwind deposition from 100-310 m from spray centerline