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A REMOTELY PILOTED VEHICLE (RPV) FOR ULV EXPERIMENTATION[1]

GARY L. BENZON[2], ROBERT W. LAKE AND FRANK J. MURPHEY[3]

Department of Entomology and Applied Ecology, University of Delaware, Newark, DE 19717-1303

To provide adequate spray droplet density with an ultra-low volume of liquid, the spray material must be atomized into small droplets, typically less than 100 μm in diameter. Such droplets drift out of the target area with air currents. Where existing insecticides are being adapted for ultra-low volume (ULV) application, or as new insecticides and drift-control additives are developed for ULV use, considerable field experimentation will be required to minimize drift and determine efficacy. The use of full-scale aircraft for experimentation is expensive and may be cumbersome where repeated small-scale tests are desired. Some workers have developed methods of simulating ULV aerial applications with ground-mounted equipment (Mount et al. 1970). Though such models were useful in the study of spray droplet formation and the behavior of droplets under certain controlled conditions of flight velocity, crosswind and turbulence, they were not capable of duplicating most normal atmospheric phenomena or the turbulence created by an aircraft in free flight. Furthermore, their utilization could not be extended to field plot experimentation.

Whitmyre and Murphey (1973) constructed a remotely piloted vehicle (RPV) with a miniaturized ULV spray system, but poor reliability and insufficient payload capacity severely limited its utility. Other workers have recently constructed and tested larger and more complex RPVs for experimental applications of microbial insecticides and sampling of pollen, plant pathogens and insects (Kaniuka 1985).

The purpose of the work reported here was to develop a prototype RPV with the following characteristics:

1. Payload capacity of at least 5 kg while maintaining adequate performance and transportability.
2. Ability to utilize less than optimal testing sites, especially in regard to take-off and landing area.
3. Cargo bay of at least 10,000 cm^3 with no intrusion by radio equipment or other components. Bay must be accessible in the field without dismantling any portion of the aircraft.
4. Power plant of high reliability and sufficient thrust to achieve the desired payload and performance per #1 and 2 above, and must be commercially available.
5. Reliable radio-control system having servos of sufficient thrust to activate control surfaces reliably, and mounted in a compartment isolated from the cargo bay, and must be commercially available.
6. Endurance of at least 30 minutes at full throttle.
7. Single-handed assembly and operation in the field.
8. A spray system of at least 4 liters capacity, constructed of corrosion-resistant materials, with precisely regulated pressurization to at least 3.5 atm, and a reliable shut-off valve.

A commercially available kit of a ¼ scale Piper J-3 Cub (Bud Nosen Models, Box 105M, Two Harbors, MN 55616) was subsequently constructed (Fig. 1). The model was not intended for this purpose, and extensive modifications were required to increase structural strength and payload capacity, to improve flight characteristics with a payload, and to accommodate a spray system (Table 1). A modified chain-saw engine of 33 cc displacement (EWH Specialties, Inc., 607 E Abrams, Suite 10, Arlington, TX 76010) was used with a 50.8 cm propeller. A 7 channel radio-control system (Kraft Systems, Inc., 450 West California Ave., Vista, CA 92083), operated the rudder, elevator, ailerons, flaps, throttle, and spray valve. Complete construction details can be found in Benzon[4].

The spray system consisted of a cylindrical 4.4 liter capacity tank fabricated from 0.030 in.

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[2] Current address: Department of Entomology, North Carolina State University, Box 7613, Raleigh, NC 27695-7613.

[3] Deceased. September 27, 1979.

[4] Benzon, G. L. 1983. An improved remote-piloted miniature aircraft for ultra-low volume aerial application. Unpublished Master's Thesis. Department of Entomology and Applied Ecology, College of Agriculture Sciences, University of Delaware, Newark, DE 19717-1303.

Fig. 1. The improved remote-piloted miniature aircraft.

stainless steel, a regulated pressurization system utilizing 10 ounce Ansul™ CO_2 cartridges (available from most fire equipment suppliers) and a servo-operated toggle valve. Fill and drain spouts, regulator adjustment, and pressure gauge were all visible and accessible without removing any aircraft component. Spray delivery lines extended along booms under both wings to conventional nylon nozzle bodies.

Table 1. Dimensions and performance of the remotely piloted vehicle (RPV).

Wingspan	285.8 cm
Wing area	1.215 m^2
Length overall	177.8 cm
Weight	
Aircraft w/o spray system or fuel	9.35 kg
Spray system (tank, regulator, servo, booms, nozzles), empty	2.75 kg.
Spray tank capacity	4.25 kg
Fuel tank capacity	0.90 kg
Gross weight, spray and fuel tanks full	17.25 kg
Payload, including spray system	7.0 kg
Payload bay volume	16,600 cm^3
Airspeed, maximum with spray equipment attached	88 km/hr
Take-off roll, 0.9 kg fuel, 1.0 kg spray material, grass surface, no wind	28 m
Landing roll, 0.9 kg fuel, spray tank empty	30–35 m
Endurance, 0.9 kg fuel, full throttle	40–50 min

With both wings removed, the aircraft was transported to test sites in a station wagon. All preparations for flight were performed in less than 15 minutes.

To evaluate the aircraft, 77 flights were made, 52 for pilot familiarization and 23 for calibration. Calibration flights were conducted to determine the swath width and spray droplet size spectrum resulting from various tank pressures, nozzle types and orientations, and application heights. For the first 17 calibration flights, a mixture of ethylene glycol and vegetable dye was utilized to simulate insecticide concentrates, and actual insecticide formulations were used in the remaining flights. Spray droplets were collected on silicone (General Electric Dri-Film™) coated microscope slides affixed to stakes at 3 m intervals along a baseline perpendicular to the flight path. Mass median diameter, droplet density, and effective swath width were determined from these slides.

The aircraft was used in a study designed to evaluate the toxicity of two mosquito adulticides to larvivorous fish inhabiting salt marshes (T. N. Mather, unpublished data). Two plots, 0.6

and 0.8 ha, were located on opposite sides of, and directly adjacent to a road extending into a salt marsh in Sussex County, Delaware. Ten data collection stations were located on each plot in a semi-random manner as required by the conjunct field study. A silicone coated microscope slide clipped to a stake 50 cm high was placed at each station to monitor spray coverage.

The 0.6 ha plot (Plot A) was sprayed with undiluted (91%) malathion at 0.22 liter/ha. The 0.8 ha plot (Plot B) was sprayed with naled at 0.071 liter/ha a.i. diluted to 0.22 liter/ha in isopropanol. Both materials were applied with two #8001 flat fan nozzles, one mounted below each wing and oriented 35 degrees forward of the vertical position. Plots were sprayed from a height of 5.5 m with successive parallel 15.25 m wide swaths until completely covered. Swaths were flown only in one direction, from markers on one side of the plot directly toward the "pilot" standing on the opposite side. Take-offs and landings were made from the adjacent road.

Flying this aircraft was more difficult than smaller models flown by hobbyists, although maneuverability was quite good even at low airspeeds. Under the calm conditions during most spray flights, ability to control the aircraft along a given flight line was within ± 1 m vertically and ± 1.5 m laterally, provided the aircraft was headed directly toward the pilot. Precision could be increased with practice. Limitations in visibility and orientation restricted the length of a continuous swath to ca. 200 m in open terrain.

The aircraft was flown with 2 kg of liquid in the spray tank and 0.9 kg of fuel, bringing the gross weight to 15 kg. The aircraft would fly with the additional 2.25 kg required to fill the spray tank to capacity if sturdier landing gear were mounted, but further increases in gross weight beyond 17.25 kg would have degraded performance.

Field plot applications, which were both completed in one evening, proceeded without complication or equipment malfunction. Plot A was sprayed with malathion in 5 successive swaths. All of the 10 stations recorded the impingement of droplets with a mean density of 1.69 (S.D. = 0.74) droplets/cm^2 (10.9 droplets/in^2). This met label specifications for ULV aerial application of malathion for adult mosquito control (American Cyanamid 1977). Plot B was sprayed immediately thereafter with the naled/alcohol solution in six successive swaths. Nine of the 10 stations recorded droplets with a mean density of 1.75 (S.D. = 2.0) droplets/cm^2 (11.3 droplets/in^2). There was considerable variability in both the droplet density and droplet size between stations in plot B. This was attributed to the use of a volatile diluent. However, the aircraft was successfully utilized for multiple field plot applications within a single brief time period without complications. The time consumed by certain phases of operation were as follows: assembly and preparation, 15 min.; application flights, 6–8 min. each; draining, flushing and refilling spray tank between flights, 15 min.; cleaning and disassembly of aircraft, 15 min. Total time elapsed from removal of disassembled aircraft from an automobile, through both application flights to subsequent disassembly, was ca. 59 minutes. Total fuel cost was $.30. All of the operations listed can be performed by one person. However, for multiple swaths, at least one assistant was found to be useful in preventing the pilot from losing his footing while walking from one swath marker to the next, as unbroken visual contact with the aircraft must be maintained while it is airborne.

A total of 77 flights made with no major damage showed that a properly constructed and skillfully piloted vehicle of this type can be reliable. Control was sufficiently precise that uniform applications over field plots could be made with multiple swaths of up to 200 m in length. Its versatile configuration would allow various arrangements of spray equipment including the use of small electric rotary nozzles. Though an RPV of this size cannot perfectly simulate application by a full-scale aircraft, it can be a useful, economical, and reasonably convenient tool for the type of ULV experimentation described. It may be especially useful for continuous research requiring repeated aerial applications to field plots in unobstructed areas.

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