THE IMPACT OF SPRAYING SYSTEMS, DROPLET SIZE DISTRIBUTION (IN MICRONS), AND SPRAY WIDTH ON THE EFFICIENCY OF AGRICULTURAL AGRO-DRONES

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Abstract:*This research explores the critical technical parameters governing the efficacy of liquid chemical application via agricultural drones. The study focuses on the atomization process, specifically the Volume Median Diameter (VMD) of droplets measured in microns, and how the effective spray width influences overall operational productivity. By examining the correlation between centrifugal nozzle speed and droplet dispersion, the paper identifies the optimal settings to maximize leaf coverage while mitigating the risks of chemical drift and evaporation. The findings provide a technical framework for improving precision in aerial crop protection.*

Keywords:*Agro-drone, droplet size, micron (μm), spray width, centrifugal atomizer, atomization, VMD, crop protection efficiency.*

Annotatsiya:*Ushbu tadqiqot qishloq xo'jaligi dronlari orqali suyuq kimyoviy moddalarni purkash samaradorligini belgilovchi muhim texnik parametrlarni o'rganadi. Tadqiqot atomizatsiya jarayoniga, xususan, mikronlarda o'lchanadigan tomchilarning o'rtacha hajmiy diametriga (VMD) va purkash kengligining umumiy ish unumdorligiga ta'siriga qaratilgan. Markazdan qochma purkagich tezligi va tomchilar dispersiyasi o'rtasidagi bog'liqlikni tahlil qilish orqali, dori isrofini va bug'lanish xavfini kamaytirgan holda barg qoplamasini maksimallashtirish uchun optimal sozlamalar*

aniqlangan. Tadqiqot natijalari aviatsiya orqali o‘simliklarni himoya qilishda aniqlikni oshirish uchun texnik asos bo‘lib xizmat qiladi.

Kalit so’zlar:*Agro-dron, tomchi o‘lchami, mikron, purkash kengligi, markazdan qochma purkagich, atomizatsiya, VMD, ekinlarni himoya qilish samaradorligi.*

Introduction. The transition from ground-based spraying to drone-based aerial application has introduced a new set of variables in agrotechnology. Unlike traditional sprayers that rely on high water volumes, drones utilize Ultra-Low Volume (ULV) technology, where the concentration of the active ingredient is higher and the liquid is broken down into much finer droplets. The core of this process lies in the "spraying system," which must balance the need for small droplets (to ensure high leaf surface coverage) and large droplets (to resist wind drift). Understanding the distribution of these droplets in microns and the resulting effective spray width is essential for achieving the biological efficacy required for pest and disease control.

Literature Review. The science of atomization in aerial application has been extensively documented by researchers such as Hoffmann and Hewitt (2012), who established that droplets smaller than 100 microns are highly susceptible to off-target movement, while those larger than 400 microns often bounce off the leaf surface. In recent years, the focus has shifted to "intelligent atomization."

Research by Lan et al. (2017) demonstrated that the use of centrifugal (rotary) nozzles on drones allows for a more uniform droplet spectrum compared to hydraulic pressure nozzles. Locally, in the context of Uzbekistan’s arid climate, Rahimov (2023) highlighted that low humidity levels can cause a 200-micron droplet to shrink by half its size within seconds of release, significantly affecting the "effective spray width." These studies suggest that while a wider spray path increases gektar-per-hour productivity, it often comes

at the cost of deposition uniformity if the aerodynamic factors are not strictly controlled.

Methodology. This study utilized a hexacopter drone equipped with an integrated intelligent spraying system featuring brushless centrifugal nozzles.

- Testing Equipment A laser diffraction particle size analyzer was used to measure droplet diameters in a controlled wind tunnel environment.
- Field Trials Conducted on a cotton field using water-sensitive papers (WSP) to map the deposition density.
- Variables The rotational speed of the atomizer disk was varied between 4,000 and 16,000 RPM. The flight altitude was fixed at 2.5 meters.
- Analysis Digital imaging software was used to count the number of droplets per square centimeter (drops/cm^2) and calculate the VMD.

Results. The experimental data indicates a non-linear relationship between the atomizer's mechanical speed and the resulting droplet size. Increasing the disk speed effectively shears the liquid into finer particles but expands the variance in the spray pattern.

Table 1.

Interaction between Atomizer Speed, Droplet Size, and Spray Performance

Atomizer Speed (RPM)	Droplet Size (VMD)(0.5 µm)	Effective Spray Width (m)	Coverage Density (drops/cm2)	Drift Risk Index
4,000	420	4.0	18	Very Low
7,000	280	5.0	35	Low
10,000	190	5.8	52	Medium
13,000	130	6.5	68	High
16,000	85	7.2	41 (loss due to drift)	Very High

The results confirm that the "sweet spot" for agricultural application is between 7,000 and 10,000 RPM, providing a droplet size of 190-280 microns.

Discussion. The discussion of these results highlights a critical trade-off in drone operations. A wider spray width (e.g., 6.5 meters) is commercially attractive because it allows the drone to cover more land in a single battery cycle. However, as shown in the results, reaching a 6.5-meter width often requires smaller droplets (130 microns) which are light enough to be pushed outward by the rotor's lateral air currents.

The primary issue with ultra-fine droplets (under 150 microns) is their interaction with the "Boundary Layer" of the crop. While they provide excellent penetration into dense canopies, they lack the kinetic energy to overcome the upward thermal currents common in midday heat. This leads to a phenomenon where the "effective" spray width is actually smaller than the "visual" spray width, as the outermost droplets evaporate or drift before reaching the target.

Furthermore, the uniformity of the spray width is affected by the drone's "swath overlap." To maintain a consistent 90% coverage across a field, the flight paths must be calculated with a 20-30% overlap. This compensates for the "bell-shaped" distribution curve inherent in centrifugal nozzles, where the concentration of liquid is highest directly under the nozzle and tapers off toward the edges of the spray width.

Conclusion. In conclusion, the efficiency of an agro-drone is not merely a product of its flight speed but a calculated balance of micron-level atomization. For most field crops, maintaining a droplet size of 200-250 microns ensures the best compromise between coverage and environmental safety. Future drone configurations should incorporate real-time weather sensors that automatically adjust the centrifugal disk speed to maintain the target VMD regardless of changes in wind speed or humidity. This level of technical integration will define the future of sustainable and precise plant protection.

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