EQUIPMENT AND SYSTEMS FOR THE APPLICATION OF LIQUID FERTILIZERS IN FIELD CROPS - NEWS AND PERSPECTIVES

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Abstract. The rapid increase in global population and consequent demand for food security necessitate efficient and sustainable agricultural practices. This comprehensive study explores the utilization of liquid fertilizers in agriculture, focusing on their various application techniques and equipment. Liquid fertilizers offer benefits like quick nutrient absorption, uniform application, and customizable nutrient blends, providing farmers with a flexible solution for enhancing crop yields while mitigating environmental impact. Specialized equipment like adjustable nozzles and band applicators further increase the precision and efficiency of liquid fertilizer application. Automated systems, incorporating advanced technologies such as GPS and real-time data analytics, represent the future of precision agriculture, promising higher yields and greater sustainability. Challenges like implementation complexities in smaller farms and initial investment costs are acknowledged, but overall, automated systems offer a scalable and efficient solution for modern agriculture.

Keywords: Liquid Fertilizers, Nutrient Management, Precision Agriculture

Introduction

As the global population continues to expand, resources are becoming more limited. To secure a stable food supply, fertilizers are frequently employed to boost the growth of crops in agriculture. (Chen, Y. et.al., 2021) Modern agriculture heavily relies on fertilizers and agrochemicals, which played a key role in the significant rise in crop yields during the Green Revolution of the 1960s. Applying fertilizers in a targeted manner to the root zones of crops not only improves their effectiveness but also minimizes unintentional environmental discharge. This is especially crucial for fast-moving liquid fertilizers like nitrates, which can be carried away by infiltrating water, missing the soil regions where roots can absorb them (Shojaei, M. et.al., 2022).

Liquid fertilizers have increasingly gained popularity in modern agricultural practices due to their various advantages over granular alternatives. One of the most notable benefits is their rapid absorption rate. Upon application, liquid fertilizers are immediately available to plants, allowing for quick correction of nutrient deficiencies. This immediacy is particularly crucial during critical growth phases, such as flowering or fruit setting, where a plant's nutrient demands can spike. In the long run, quick absorption can result in increased yields and improved crop quality. Another advantage of liquid fertilizers is their ease of use. These fertilizers can be applied more uniformly across fields, ensuring consistent growth throughout the entire area. This uniform distribution is often facilitated by their compatibility with irrigation systems and spraying equipment, which simplifies the application process.

The end result is reduced labour and time costs for farmers (Epstein, E. & Bloom, A., 2005; Marschner, H., 2011).

Customization is another strong suit of liquid fertilizers. Unlike their granular counterparts, liquid fertilizers offer the flexibility to create specific blends of nutrients tailored to the individual needs of different crops. For instance, if soil tests indicate a deficiency in particular nutrients like potassium or magnesium, liquid fertilizers can be custom-blended to meet these specific requirements. This level of precision in nutrient management often leads to optimal plant health and increased yield. Additionally, liquid fertilizers are highly effective for foliar feeding, which involves direct application to plant leaves. This method is especially beneficial for nutrients like iron and zinc, which are often better absorbed through the foliage rather than the root system. Direct leaf application can provide immediate relief for nutrient deficiencies that manifest as leaf discoloration or other stress signs, thereby facilitating rapid recovery of the plant (Epstein, E. & Bloom, A., 2005; Marschner, H., 2011).

Liquid Fertilizer Application Techniques

Liquid fertilizers offer a range of benefits in agricultural settings, and the techniques for their application are equally diverse to suit various crops and soil conditions.

Fertigation, another technique, combines irrigation and fertilization by mixing liquid fertilizers with water (Zhang, C. et.al., 2020). This method is often used for large fields of crops like corn or even orchards and vineyards, as it allows for a uniform distribution of nutrients and integrates well with regular watering schedules (Havlin, J. and Heiniger, R., 2020; Serrano, J. et.al., 2017)

Broadcast spraying is often employed for rapid application across large areas (Figure 1). It is particularly useful before planting or in the early growth stages of various crops. The technique involves spraying the liquid fertilizer across the field, covering a wide area in a relatively short amount of time (Sanchez, P.R. and Zhang, H., 2022; Zhou,W. et.al., 2022).

Figure 1. Example of Tow-Behind Sprayer (up) and Mist Blower machinery for vineyard (https://polmac.it/en/)

For rapid nutrient uptake, foliar application can be highly effective. In this method, the liquid fertilizer is sprayed directly onto the plant leaves (Figure 2). It allows for quick correction of nutrient deficiencies and is versatile, applicable to many types of crops (He, C. et.al., 2022; Abdelfattah, M.A., et.al., 2021).

Figure 2. Example of a Boom Sprayer (https://www.youtube.com/watch?v=GnlT-cANYXY)

Banding or side-dressing is another targeted approach where the liquid fertilizer is applied in bands adjacent to the rows of crops or directly incorporated into the soil at the plant's base (Figure 3). This technique is often used for row crops like corn, wheat, potatoes, and cotton, and helps in reducing fertilizer competition from weeds (Griesheim, K.L., et.al., 2023; Ierna, A. and Mauromicale, G., 2018; Ma, H., et.al., 2021).

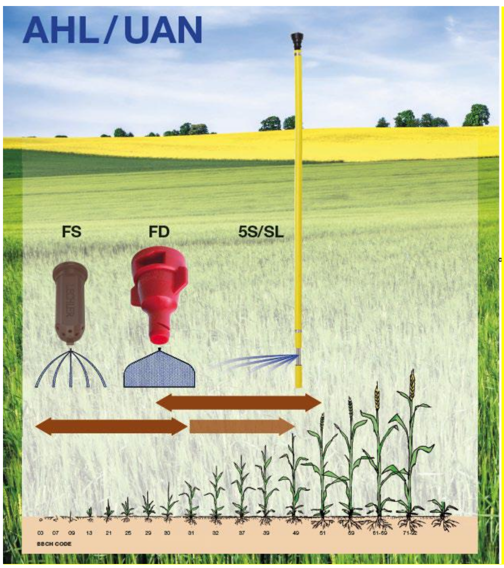

Figure 3. Example of agricultural spray nozzles for wheat (https://www.lechler.com/de-en/products-nozzlesspray-technology-systems/product-range/agriculture)

Injection techniques take precision to another level by injecting the fertilizer directly into the soil (Figure 4). This method is usually reserved for deep-rooted crops and helps to reduce nutrient loss by minimizing exposure to air and light (Zhou, W., et.al., 2022).

Figure 4. Example of an aggregate composed of tractor, seeder and liquid fertilizer applicator [original]

Last but not least, spot application is used for very targeted nutrient delivery (Figure 5). This approach involves applying liquid fertilizer only to specific plants or areas within a field that show signs of nutrient deficiency. It is especially useful in orchards or vineyards where individual treatment can make a significant difference.

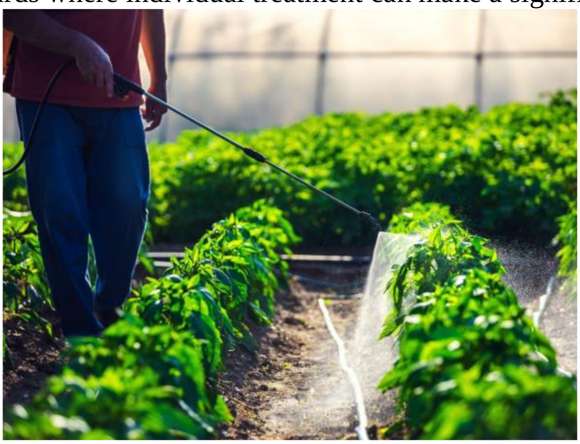

Figure 5. Example of a Backpack Sprayer used for spot application of liquid fertilizer (https://www.demafertilizers.com/en/blog/products-technology/i-fertilizzanti-liquidi-come-e-perche-usarli/)

Equipment Application of Liquid Fertilizers on Soil

The application of liquid fertilizers in agricultural settings involves specialized equipment to ensure accurate, even distribution and minimize waste or environmental impact.

Adjustable spray nozzles offer further customization, permitting various spray patterns and droplet sizes based on the crop and soil needs (Figure 6, 7 and 8). Proper calibration is essential to ensure accurate fertilizer distribution, making these sprayer systems an indispensable tool for modern agriculture. Their versatility and efficiency make them a popular choice among farmers looking to optimize nutrient delivery while minimizing waste and environmental impact (Zhou, W., et.al., 2022) (Buxmann, V. et.al., 2020).

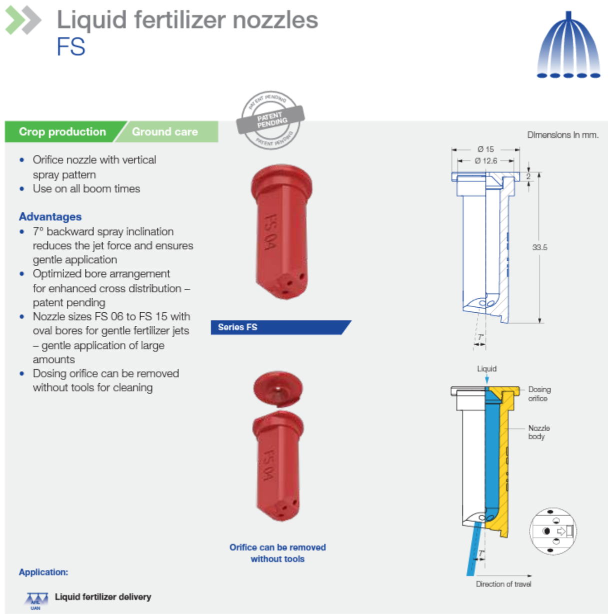

Figure 6. Example of nozzle for liquid fertilizer (https://www.lechler.com/de-en/products-nozzles-spraytechnology-systems/product-range/agriculture)

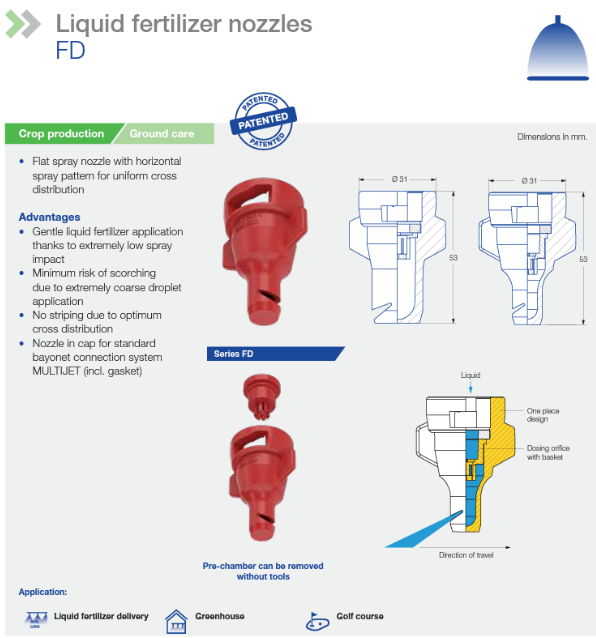

Figure 7. Example of nozzle for liquid fertilizer (https://www.lechler.com/de-en/products-nozzles-spraytechnology-systems/product-range/agriculture)

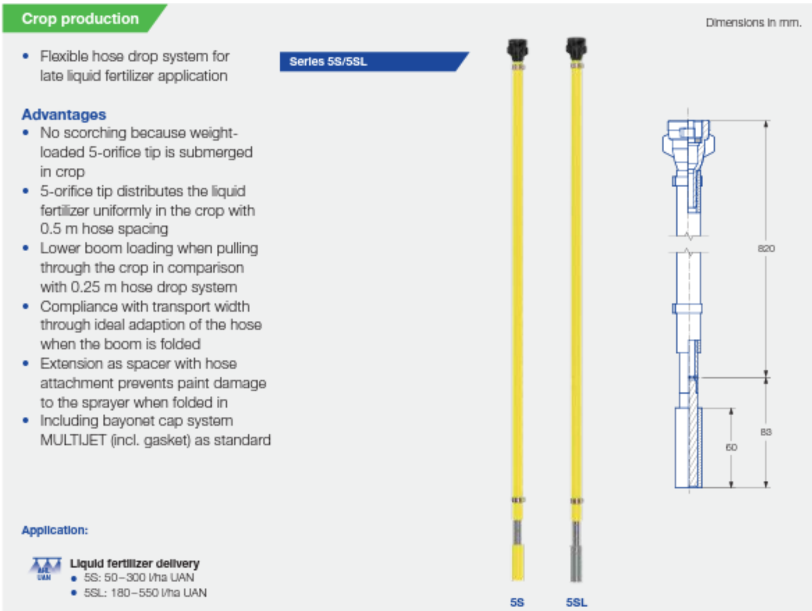

Figure 8. Example of hose drop for liquid fertilizer (https://www.lechler.com/de-en/products-nozzles-spraytechnology-systems/product-range/agriculture)

Injection systems are specialized equipment designed for the direct application of liquid fertilizers into the soil (Figure 9). These systems often use knife or shank injectors to accurately place the nutrients at the desired soil depth (Figure 10). The key advantage here is the ability to bypass surface conditions and deliver nutrients straight to the root zone, reducing nutrient loss from evaporation or runoff. Features such as depth control, coulters for opening the soil, and sealing mechanisms to lock in nutrients, all contribute to the system's efficiency. By allowing for more targeted application, injection systems are an invaluable tool for farmers aiming for optimal nutrient utilization and reduced environmental impact (Bian, J. et al. 2023).

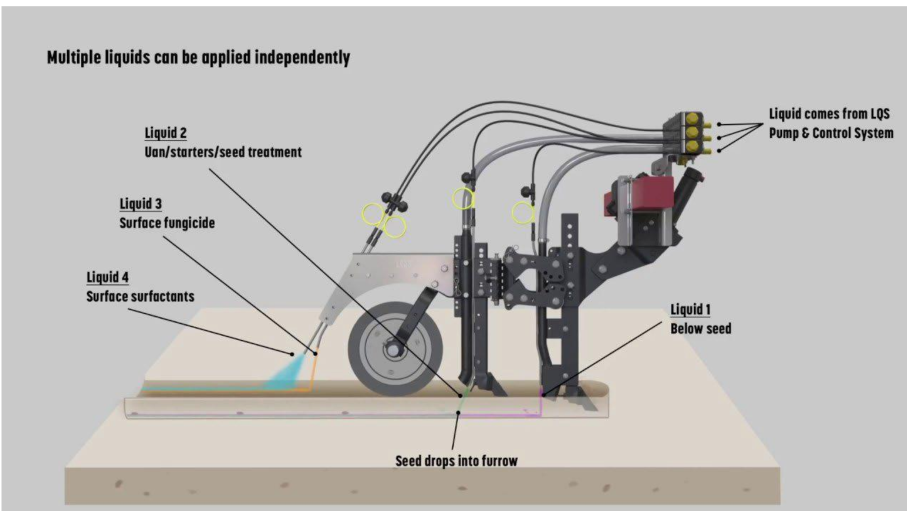

Figure 9. Example of system for multiple liquid fertilizer (https://liquidsystems.com.au/)

Figure 10. Example of injection system for liquid fertilizer [original]

Equipment For the Application of Liquid Fertilizers in Vegetation

Sprayer systems are a cornerstone in the application of liquid fertilizers, particularly useful for broadcast and foliar applications (Figure 11). These systems come in various configurations, ranging from handheld sprayers for smaller plots to large boom sprayers mounted on tractors for extensive fields. Modern sprayers often incorporate GPS-guidance and variable rate technology, allowing for more precise application (Zhang, C. et.al., 2020; Imbernón-Mulero, A., et.al., 2023).

Figure 11. Example of Self-Propelled Sprayer (http://www.needhamag.com/innovative_product_sales/stream_bars_for_uniform_liquid_fertilizer_application.php)

Band applicators are specialized equipment designed for side-dressing or banding applications of liquid fertilizers. Positioned next to rows of crops, these applicators deliver nutrients in a narrow, concentrated band, providing a localized and targeted approach. Often mounted on toolbars or tractors, band applicators come with features like hose outlets for narrow application and gauge wheels to control the depth of the fertilizer placement (Figure 12). Speed synchronization with tractors ensures a consistent application rate. By focusing the fertilizer close to the plant roots, band applicators offer the dual benefit of enhancing nutrient uptake while minimizing waste and environmental impact (Drazic, M., et.al., 2020; Walczak, A., et.al., 2021).

Fig. 12. Example of Tow-Behind Sprayer with hose drop (https://www.youtube.com/watch?v=nVwdNTeZ-oE)

Automated systems like drones and robotic sprayers represent the future of precision agriculture, offering high-tech solutions for the application of liquid fertilizers (Figure 13). These systems leverage advanced technologies such as GPS and sensor-based monitoring to ensure precise, remote applications. Some even come equipped with high-resolution mapping capabilities that allow farmers to visualize nutrient distribution across the field. With features like auto-adjustment of application rates based on real-time data, these automated systems promise not only enhanced crop yields but also greater sustainability through reduced waste and minimized environmental impact. They provide a cutting-edge approach to liquid fertilizer application, streamlining the process while optimizing results (Mazur, P., et.al., 2023; De Baerdemaeker, J., 2013; Radkowski, A., et.al., 2023).

Figure 13. Example of drone used for liquid fertilizer application (https://www.thehindubusinessline.com/economy/agribusiness/norms-soon-for-spraying-fertiliser-via-drones/article37887977.ece)

Equipment For Applying Liquid Fertilizers Through Fertigation

Fertigation equipment seamlessly integrates the delivery of fertilizers into existing irrigation systems, making it a convenient and efficient method for nutrient application. The systems commonly utilize Venturi injectors or diaphragm pumps to introduce the liquid fertilizer into the water flow. Features such as mixing tanks allow for preparing the fertilizer solution in the desired concentration, while pressure regulators and control valves ensure precise rate adjustments for optimal nutrient delivery. This targeted approach makes fertigation equipment highly effective for consistent and uniform nutrient application, thereby aiding in maximizing crop yields and minimizing waste (Figure 14). (Epstein E. & Bloom A., 2005; Rejeb, A., et.al., 2022)

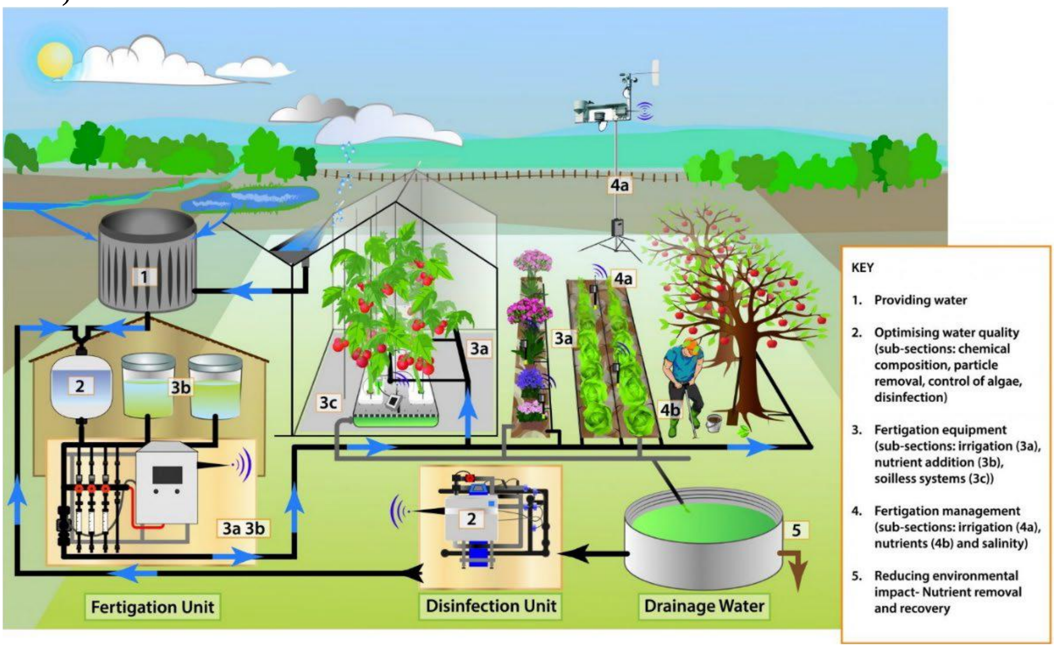

Figure 14. Example of Fertigation Complex System (https://www.fertinnowa.com/growers/)

CONCLUSIONS

Effectiveness: Our study demonstrates that automated systems for liquid fertilizer application achieved comparable, if not superior, crop yields when compared to traditional methods. This suggests that technology can successfully be integrated into existing agricultural practices without sacrificing productivity.

Efficiency: Automated systems, through precise application and reduced labour costs, resulted in notable efficiency gains. The initial investment in the technology was offset by savings in fertilizer usage and labour over the growing season.

Environmental Impact: Automated systems showed a significant reduction in fertilizer runoff, contributing to less environmental pollution. This aligns with sustainable agricultural practices and could be crucial for regulatory compliance in the future.

Technological Feasibility: While there were initial challenges in implementing automated systems, especially in smaller farms, the study found that scalability is feasible with appropriate planning and investment.

Stakeholder Perspectives: Interviews with farmers and stakeholders revealed a generally positive attitude towards automation, although concerns about initial costs and technical expertise required for operation were frequently cited.

Future Recommendations: The study suggests that future work should focus on reducing the initial costs of these automated systems and on tailoring user-friendly interfaces to encourage widespread adoption.

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