Wick and capillary hydroponic systems

Grant Kinkead
Independent Researcher, Melbourne, VIC, Australia
grant@kinkead.au

***Abstract*—Wick and capillary hydroponic systems supply nutrient solution to plant roots without active pumping. Their operation relies on capillary forces acting through absorbent materials or narrow liquid pathways that connect a reservoir with the root zone. This paper synthesises the operating logic of these passive systems, explains why delivery capacity can become limiting as plant water demand increases, and distinguishes system-level capillary delivery from detailed substrate physical properties. The evidence indicates that passive movement can establish a functional root-zone supply pathway, but that this pathway has finite capacity and should not be treated as equivalent to active circulation. Crop type, developmental stage, root-zone conditions, and environmental demand can alter the supply requirement placed on a system. Available literature therefore supports a demand-and-pathway interpretation of wick systems, while providing limited direct evidence for universal capacity thresholds or design rules. Wick and capillary arrangements are best understood as context-dependent passive delivery systems whose suitability depends on whether the pathway can sustain crop demand under the conditions of use [1], [2], [3].**

I. Introduction

Wick and capillary hydroponic systems provide a passive means of delivering nutrient solution to plant roots. In these arrangements, a reservoir is connected to the root zone through a wick, capillary mat, or comparable absorbent pathway. Capillary irrigation literature describes this pathway as the means by which water or nutrient solution can move without an actively pumped circulation loop. The system therefore answers a basic hydroponic question: solution can reach roots through capillary forces when a suitable liquid connection is maintained between the reservoir and root zone. This operating principle is important because it defines wick systems by their delivery mechanism, rather than by the presence of a reservoir or supporting substrate alone [1].

Passive delivery also creates a practical constraint. Capillary wick systems have limited supply capacity and are generally unsuitable for heavy-feeding crops or crops with high water demand. A reservoir may contain ample solution, yet the system can still be inadequate if the capillary pathway cannot convey solution at the rate required by the plant. The central design issue is consequently the relationship between pathway capacity and plant demand, not merely the total volume stored. This distinction becomes increasingly important when crop requirements change during development or in response to environmental conditions [1].

This paper examines wick and capillary hydroponic systems as root-zone delivery arrangements. It first defines the scope of passive capillary supply within broader soilless cultivation, then explains the relationship between capillary movement and changing crop demand. It next synthesises relevant evidence from wider hydroponic root-zone literature and identifies the boundaries of current knowledge. The analysis distinguishes the system-level question of how solution travels from a reservoir to roots from detailed treatment of media physical properties. Those properties can influence the receiving root zone, but they do not replace explanation of the delivery pathway itself [1].

II. Background and Scope

Soilless cultivation includes systems that use solid substrates and systems that use water-based root environments. This distinction is relevant to wick and capillary arrangements because a substrate may support roots and receive nutrient solution, while the capillary pathway determines how that solution reaches the root zone. Reviews of soilless cultivation identify water-air conditions and substrate context as relevant to crop growth, but do not present these factors as a complete account of capillary delivery. The appropriate analytical boundary is therefore clear: root-zone conditions matter to performance, whereas the present focus is the passive route that connects nutrient solution storage with the root zone [4].

The classification of soilless systems also shows why wick systems should not be assumed to operate like all other hydroponic arrangements. Substrate-based and water-based systems employ different nutrient-delivery structures and design requirements. A wick system may contain both a substrate and a reservoir, but its defining feature is passive transport through an absorbent pathway rather than programmed irrigation or continuous recirculation. This distinction allows the system to be considered as a coherent delivery architecture. It also prevents broad descriptions of hydroponics from being misread as direct evidence of capillary-system performance [3], [4].

Crop water delivery is influenced by crop type, developmental stage, substrate capillarity, and irrigation-system choice. These factors are especially important in a passive arrangement because a wick does not actively increase supply in response to a changing requirement. A pathway that is adequate for one crop or growth stage may be less adequate as demand rises. The available evidence supports this demand-sensitive interpretation, but it does not directly establish a general threshold at which passive capillary delivery fails. Any claim about universal capacity limits would therefore exceed the available evidence and should be treated cautiously [2].

III. Core Concepts and Mechanisms

The essential mechanism in a wick system is capillary action through an absorbent pathway. A connected wick or mat provides a route by which nutrient solution can move from a reservoir towards the root zone without pump-driven flow. This mechanism is system-level: it explains how passive liquid movement establishes a supply connection, not how every substrate stores or distributes water internally. The implication is that continuity of the pathway is fundamental to system operation. If the pathway is the means of transport, its capacity is also the practical limit on what the system can provide to roots [1].

Wick systems are recognised within the broader range of soilless cultivation methods, but broad classifications offer limited explanation of the capillary forces that make them operational. Their key difference from actively managed systems is not simply lower equipment complexity. Rather, the source-to-root connection depends on passive movement through the available pathway. This makes the system's operating logic inseparable from the question of supply adequacy. A reservoir establishes a potential source of nutrient solution, whereas the wick determines whether that source can be delivered effectively to the root zone under the prevailing demand [3].

The need to match delivery with crop demand provides the most useful interpretation of system limitations. Soilless cultivation literature notes that water delivery must be matched to crop requirements and that system selection affects root-zone buffering. In a wick arrangement, passive supply must accommodate demand without the corrective response supplied by active circulation or scheduled irrigation. Crop development and changing conditions can therefore alter the adequacy of a previously suitable arrangement. The evidence supports this relationship conceptually, while leaving detailed capillary-flow limits dependent on conditions not quantified in the available sources [2], [3].

IV. Evidence Synthesis

The evidence consistently places wick systems within a diverse set of soilless production arrangements, including substrate-based and water-based systems with differing design requirements. This broader context is useful because it demonstrates that nutrient delivery should be interpreted according to system architecture. Capillary irrigation evidence directly supports passive movement from a reservoir through wicks or mats, while general soilless classifications show that root-zone configurations differ substantially across cultivation systems. Together, these sources support a narrow but robust conclusion: wick systems require analysis of their specific delivery pathway rather than reliance on general claims about hydroponics [1], [3].

Literature on nutrient-solution management distinguishes recirculating management from irrigation approaches, clarifying that stored nutrient solution does not by itself constitute active circulation. This distinction is important for wick systems because their supply mechanism is passive, even when nutrient solution composition is managed elsewhere in the production arrangement. Monitoring, nutrient adjustment, and recirculation are separate questions from the physical transport of solution through a wick. Keeping these functions conceptually separate improves the explanation of passive hydroponics and avoids attributing the capabilities of actively managed systems to capillary delivery [5].

Evidence from other root-zone systems reinforces the broader principle that delivery requirements can shift over time. Research on nutrient film technique indicates that root growth and oxygen demand can progressively exceed passive transfer capacity, although it does not directly study capillary systems. Aeroponic literature similarly identifies root growth, oxygen demand, and environmental conditions as factors affecting delivery requirements. These findings cannot establish performance limits for wick systems, because the mechanisms differ. They do, however, support the cautious inference that a static delivery arrangement must be judged against changing biological demand rather than assumed sufficient throughout crop development [6], [7].

V. Practical Implications and Limitations

Wick and capillary systems should be evaluated as passive supply pathways with a finite ability to deliver nutrient solution. This framing is more useful than treating them as simplified versions of recirculating hydroponics. Existing overviews describe wick and substrate systems at a broad level, yet provide limited physical explanation of capillary action within hydroponic root zones. The practical implication is that system selection should begin with the demonstrated mechanism of reservoir-to-root transport and the anticipated crop demand. The available evidence does not support universal sizing rules, universal crop recommendations, or precise pathway-capacity thresholds [1], [8].

Substrate buffering and crop-specific demand are relevant to a wick system, but they should not be conflated with direct measures of capillary delivery capacity. Broader reviews indicate that soilless systems differ in their dependence on substrates and in the design choices that shape root-zone conditions. In a passive system, the substrate may influence the receiving environment while the wick remains the route of supply from the reservoir. The interaction is important, yet the supplied evidence does not directly quantify how substrate conditions, pathway characteristics, and crop demand combine to determine maximum sustainable passive delivery. This is a significant limitation for detailed design guidance [2], [8].

Clear system boundaries are necessary when interpreting evidence. Hydroponics, aquaponics, aeroponics, and substrate-based cultivation use different root-zone arrangements and delivery approaches. Findings from actively irrigated, recirculating, nutrient-film, or aeroponic systems can illuminate the importance of matching delivery to root requirements, but they cannot be transferred as direct evidence of capillary-wick performance. The defensible conclusion is narrower: capillary action can move nutrient solution through an absorbent pathway to roots, while the suitability of that pathway depends on demand and operating context. This boundary preserves

the distinction between system-level capillary delivery and detailed media physics [3], [5], [8].

VI. Conclusion

Wick and capillary hydroponic systems rely on passive liquid movement from a reservoir to the root zone through absorbent materials or narrow capillary pathways. Their operating logic is therefore straightforward, but their practical adequacy is conditional. The available evidence indicates that capillary pathways can supply roots without active pumping, while also showing that wick systems have limited supply capacity and may be unsuitable where crop demand is high. Broader hydroponic literature reinforces the importance of crop development, root-zone conditions, and environmental demand, but does not supply direct universal thresholds for passive systems [1], [2], [6], [7].

Further work should directly examine the interaction among capillary pathway capacity, root-zone conditions, and changing crop demand. Such evidence would improve the basis for judging when passive delivery remains adequate and when an alternative delivery arrangement is required. Until that evidence is available, wick systems should be treated as context-dependent passive hydroponic systems, assessed by the match between their physical supply pathway and the water and nutrient solution requirements placed upon it [1], [8].

Acknowledgment

The author used artificial intelligence tools to assist with manuscript drafting and revision, and with LaTeX and bibliography preparation. The author reviewed all AI-assisted output and remains responsible for the final content.

References

[1] N. P. K. Semananda, J. D. Ward, and B. R. Myers, "A semi-systematic review of capillary irrigation: The benefits, limitations, and opportunities," *Horticulturae*, 2018.

[2] R. S. Velazquez-Gonzalez, A. L. Garcia-Garcia, J. O. Barceinas-Sanchez, E. Ventura-Zapata, and J. C. Sosa-Savedra, "A review on hydroponics and the technologies associated for medium- and small-scale operations," *Agriculture*, 2022.

[3] I. A. Lakhiar, H. Yan, T. N. Syed, C. Zhang, S. A. Shaikh, M. Rakibuzzaman, and R. B. Vistro, "Soilless agricultural systems: Opportunities, challenges, and applications for enhancing horticultural resilience to climate change and urbanization," *Horticulturae*, 2025.

[4] A. Tuxun, Y. Xiang, Y. Shao, J. E. Son, M. Yamada, S. Yamada, K. Tagawa, B. Baiyin, and Q. Yang, "Soilless cultivation: Precise nutrient provision and growth environment regulation under different substrates," *Plants*, 2025.

[5] E. Fathidarehnijeh, M. Nadeem, M. Cheema, R. Thomas, M. Krishnapillai, and L. Galagedara, "Current perspective on nutrient solution management strategies to improve the nutrient and water use efficiency in hydroponic systems," *Can. J. Plant Sci*, 2024.

[6] S. Scott and C. Villouta, "Dissolved oxygen limitation and pythium root rot in strawberry nft systems: Mechanisms, research gaps, and prospects for substrate-free production," *Frontiers in Plant Science*, 2026.

[7] B. M. Eldridge, L. R. Manzoni, C. A. Graham, B. Rodgers, J. R. Farmer, and A. N. Dodd, "Getting to the roots of aeroponic indoor farming," *New Phytologist*, 2020.

[8] A. Fussy and J. Papenbrock, "An overview of soil and soilless cultivation techniques-chances, challenges and the neglected question of sustainability," *Plants*, 2022.