Algae growth and system effects

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

***Abstract*—Algae growth is a recurrent hydroponic management issue because illuminated wet surfaces may provide access to dissolved nutrients. This paper synthesises evidence on the conditions that enable algae proliferation, the operational and biological effects of excessive growth, and the distinction between algae and pathogenic organisms. The available evidence indicates that light exposure, nutrient-bearing solution, solution chemistry, temperature and oxygenation jointly affect algal development. In recirculating systems, algae may alter dissolved oxygen, pH and nutrient composition, compete with crops for resources, form aggregates relevant to filtration, and contribute to clogging-related problems. Algae are not plant pathogens, although algae-related changes to the root-zone environment may indirectly affect plant health and may coexist with independent pathogen risks. Light exclusion from reservoirs is supported as a preventative measure, but exposed channels, fittings and other wet surfaces remain relevant. The evidence does not establish universal thresholds for proliferation or uniform crop responses. Algae management should therefore focus on controlling the environmental opportunity for growth and assessing demonstrated system effects, rather than treating visible algae as proof of plant disease.**

I. Introduction

Hydroponic systems deliberately supply water and dissolved nutrients near crop roots, but these same resources can support algae wherever wet surfaces receive light. A hydroponic wastewater study documented algae-growth dynamics under measured conditions involving alkaline pH, dissolved oxygen, nitrogen, phosphorus, cooler temperatures and red-blue LED nighttime lighting. Faster colony development was associated with LED lighting under the tested cooler conditions [1]. These observations do not establish a universal threshold for algae in every hydroponic installation. They demonstrate that algae respond to an interacting environmental setting in which illumination overlaps with nutrient-bearing water. Consequently, reservoirs, channels and wet interfaces should be considered potential biological habitats when light access is not controlled.

The significance of algae extends beyond visible discolouration. Research on irrigation and production water identifies algal biomass as relevant to clogging-related contamination, nutrient runoff, biomass reduction and treatment requirements [2]. In hydroponic systems, excessive growth may therefore affect water movement, filtration and the condition of surfaces through which solution is delivered or returned. The operational problem is not merely that algae are present. It arises when biomass persists or accumulates in locations where it changes hydraulic reliability or solution management. This distinction matters because a small amount of visible growth does not establish crop damage, whereas recurring biomass in channels or water-handling components may indicate conditions that permit broader system effects.

Algae must also be distinguished from plant and human pathogens. A review of soilless cultivation identifies algae as a separate biological concern in closed systems, while recognising that algae can alter oxygen, pH and nutrient conditions relevant to plant-health risk [3]. Algae may therefore be associated with poor crop performance without directly infecting plant tissue. This paper examines why algae proliferate in hydroponic systems and what problems they can create through effects on surfaces, oxygen dynamics, resources and microbial habitat. It first defines the scope of the evidence, then explains the mechanisms of growth, synthesises reported effects and considers practical limitations.

II. Background and Scope

Research on algae in hydroponic environments addresses both biological growth and the physical consequences of biomass in water. In a hydroponic wastewater system, algal colony development was associated with aggregate growth and particle-size behaviour relevant to sedimentation and filtration. Aggregates exceeding 50 micrometres were identified as important for effective separation, and faster colony growth was associated with LED conditions in the tested setting [1]. The relevance of this evidence is that algae may affect operation as material that settles, accumulates or reaches filters, not only as dispersed cells. However, the finding derives from a particular wastewater-hydroponic context and should not be treated as a universal prediction for all reservoir designs or crops.

The scope of algae-related risk requires a distinction between nutrient-recovery organisms and pathogenic contamination. Wastewater hydroponics literature discusses algae and duckweed as organisms that can contribute to nutrient recovery, while treating pathogen internalisation, contaminant uptake and wastewater contact as separate plant and consumer-health concerns [4]. Algae can thus be biologically active in nutrient-bearing water without being infectious. Their relevance to plant health instead concerns their capacity to modify the local environmental setting or create habitat effects. This distinction prevents the inaccurate classification of all visible biological growth as disease and supports separate assessment of algae, pathogens and water-quality conditions.

Light exposure provides a practical boundary for understanding algae establishment. A hydroponic farming study states that an opaque reservoir helps prevent algae growth and identifies algae as competitors for dissolved nutrients and oxygen in solution [5]. Reservoir opacity addresses a necessary

condition for photosynthetic development, but it does not protect every wetted surface. Channels, return lines, openings and fittings may remain illuminated even when stored solution is covered. The evidence consequently supports examining the complete water pathway for illuminated nutrient-rich surfaces, while recognising that it does not provide a universal engineering specification or a single management threshold.

III. Core Concepts and Mechanisms

Algae proliferation is an ecological response to the combined availability of light, water and dissolved nutrients. Closed hydroponic systems recirculate nutrient solution, thereby producing an aqueous environment that may support algae as well as crop roots. A review of hydroponic food-production practices reports algae growth in closed systems with available nutrients and identifies related changes in dissolved oxygen, pH and nutrient composition [6]. This mechanism explains why a solution formulated for crop nutrition can also sustain algae when it is exposed to light. The resulting design implication is that nutrient management and light exclusion cannot be treated as independent controls when preventing persistent algae growth on wet system surfaces.

As algal biomass develops, it may affect the chemical conditions on which roots depend. The reviewed evidence reports that algae can alter dissolved oxygen, pH and nutrient composition, compete with crops for nutrients, and may produce toxic growth-inhibiting substances [6]. It also reports reduced lettuce fresh weight, shoot-to-root ratio, water uptake and nitrogen uptake in relevant studies [6]. These observations identify a pathway from algae growth to crop response without requiring algae to be a pathogen. The magnitude of any effect cannot be inferred from visual algae alone, because abundance, system configuration and crop response vary. Nevertheless, excessive growth warrants investigation where root-zone conditions or crop uptake are unstable.

Oxygen dynamics require particular care because algae-related effects and pathogen risks are different mechanisms. In recirculating systems, algae can modify dissolved oxygen, pH and nutrient composition, while pathogens may spread through the same water system through separate processes [6]. The available evidence supports concern that algae can contribute to an unfavourable root-zone environment, but does not justify attributing every symptom of crop stress to algae. Algae should therefore be evaluated as a potential environmental stressor, while pathogen diagnosis requires independent evidence. This distinction is essential for interpreting indirect plant-health risks without incorrectly treating algae as direct plant pathogens.

IV. Evidence Synthesis

Across the available literature, algae growth is associated with nutrient-solution conditions, light-controlled production environments, oxygenation and nutrient availability [7]. These environmental factors align with the hydroponic wastewater observations, in which lighting and water conditions coincided with reported algae-growth dynamics [1]. Together, the sources support the conclusion that algae exploit illuminated nutrient-rich wet surfaces rather than appearing randomly. They do not support a simple single-variable rule in which one pH value, oxygen concentration or nutrient measurement predicts algae outbreaks across all hydroponic systems. This limitation is operationally important because control decisions should consider the combined exposure environment rather than an isolated bulk-water reading.

The evidence distinguishes algae-related changes from pathogen risks while recognising that both can matter to plant health. Reviews report algae-associated effects on oxygen, pH, nutrients and plant growth, and separately identify pathogen risks in closed hydroponic and aquaponic systems, including indirect implications for roots and disease resistance [7]. A crop may therefore experience altered root-zone conditions in an algae-affected system without algae being the infectious cause of disease. The practical implication is that growers should investigate solution conditions and pathogen presence as related but separate questions. This approach supports more accurate diagnosis and avoids treating all biological problems in recirculating systems as equivalent.

Broader rhizosphere literature reinforces the need to interpret microorganisms according to function rather than appearance. Beneficial rhizobacteria and pathogens have different roles in plant health and defence, showing that biological activity in the root zone cannot be placed in a single harmful-beneficial category [8]. Soilless-cultivation literature similarly considers microbial effects on crop health and notes microalgae integration, but provides limited algae-specific risk analysis [9]. The defensible synthesis is therefore narrow: algae are neither automatically beneficial nor automatically pathogenic. Their significance must be established through observed effects on surfaces, solution conditions, resource competition and crop performance.

V. Practical Implications and Limitations

Nutrient availability outside the immediate root zone deserves attention because nutrient-rich water can sustain unintended biological growth. A hydroponics review reports that nitrate- and phosphate-rich discharge can promote algal growth and eutrophication [10]. This evidence supports careful management of nutrient-bearing water that is retained, exposed or discharged from a system. It does not show that reducing crop nutrition is an appropriate response to every algae problem. The source provides limited operational detail concerning excessive algae inside hydroponic equipment, so it cannot support a universal concentration limit. Its strongest implication is that nutrients are part of the enabling environment when they reach illuminated wet surfaces.

Evidence limitations constrain how confidently algae proliferation can be predicted. Wastewater hydroponics research identifies light, wastewater characteristics, pH, temperature and nutrients as relevant operating factors, but provides limited direct evidence defining the exact combinations that initiate algae growth in conventional hydroponic production [4]. This gap means that local validation is necessary before assigning

causation or selecting a system response. Assessment should connect visible algae with conditions at the affected surface, not rely only on bulk reservoir measurements. Where algae are present, water chemistry, oxygen conditions and hydraulic effects should be examined alongside crop response.

A further limitation is the temptation to use algae as a proxy for all microbial risk. Evidence on beneficial rhizobacteria and pathogen-induced plant defence clarifies that microbial functions differ, but it provides no substantive evidence that algae induce those effects [8]. It cannot therefore support claims that algae are plant pathogens or direct triggers of plant defence. The available evidence instead supports a narrower conclusion: algae may alter the physical and chemical habitat in which roots and microorganisms occur. Reliable management requires distinguishing algae growth, biomass accumulation, water-quality change and verified pathogen contamination before attributing plant-health decline to a particular cause.

VI. Conclusion

Algae proliferate in hydroponic cultivation when light reaches wet surfaces supplied with nutrient-bearing solution. Excessive growth can affect system operation through biomass accumulation and aggregate behaviour, while also altering nutrient composition, pH and dissolved oxygen and competing with crops for resources [1], [6]. Algae are not equivalent to plant pathogens, but their effects on root-zone conditions can contribute indirectly to plant-health risk and can coexist with separate pathogen hazards [3], [7].

The strongest preventative implication is to reduce light reaching nutrient solution, including through opaque reservoirs, while examining other illuminated wet interfaces throughout the water pathway [5]. Future validation should link algae abundance with solution conditions, operational effects and crop response so that algae management is based on demonstrated system mechanisms rather than visible growth alone [4], [10].

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] A. Bawiec, T. Garbowski, K. Pawęska, and K. Pulikowski, "Analysis of the algae growth dynamics in the hydroponic system with leds nighttime lighting using the laser granulometry method," *Water, Air, & Soil Pollution*, 2019.

[2] J. C. Majsztrik, R. T. Fernandez, P. R. Fisher, D. R. Hitchcock, J. Lea-Cox, J. S. Owen, Jr., L. R. Oki, and S. A. White, "Water use and treatment in container-grown specialty crop production: A review," *Water, Air, & Soil Pollution*, 2017.

[3] M. Elakrouch, M. Mohaddab, A. Rachid, and M. H. Jijakli, "Soilless agriculture at a crossroads: Strengths, challenges, and prospects of hydroponics, aquaponics, and bioponics in relation to precision farming," *Sustainability*, 2025.

[4] C. Mai, A. Mojiri, S. Palanisami, A. Altaee, Y. Huang, and J. L. Zhou, "Wastewater hydroponics for pollutant removal and food production: Principles, progress and future outlook," *Water*, 2023.

[5] J. Arshad, F. Azeem, A. Butt, M. Chaudhary, R. S. Safdar, M. K. Joyo, I. Ahmad, P. Valsalan, and H. M. Ahmed, "Ai-enabled iot-based hydroponic farming with embedded automation and nutrient prediction," *Future Internet*, 2026.

[6] S. Wang, Y. Kleiner, S. M. Clark, V. Raghavan, and B. Tartakovsky, "Review of current hydroponic food production practices and the potential role of bioelectrochemical systems," *Reviews in Environmental Science and Bio/Technology*, 2024.

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

[8] L. Zhu, J. Huang, X. Lu, and C. Zhou, "Development of plant systemic resistance by beneficial rhizobacteria: Recognition, initiation, elicitation and regulation," *Frontiers in Plant Science*, 2022.

[9] 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.

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