African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 5, Issue 4, 2026
Page No: 353-361
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2025: 1.126 SJIFactor 2024: 6.752 معامل التأثير العربي 2025: 1.65

Design, Commissioning, and Preliminary Comparative Evaluation of Basil (*Ocimum basilicum L.*) Growth, Biomass Quality, and Water -Quality Dynamics in Recirculating Aquaponic and NFT Hydroponic Systems

Ahmed Shaban Ebdiwy [1 *], Ibtihal Al-Basheer Elter [2]
[1] Department of Agricultural Engineering, Faculty of Agriculture, University of Tripoli, Tripoli, Libya
[2] B.Sc. Graduate, Department of Agricultural Engineering, Faculty of Agriculture, University of Tripoli, Tripoli, Libya

تصميم وتشغيل وتقييم ومقارنة أولية لنمو الريحان *(Ocimum basilicum L.)* وجودة كتلته الحيوية وكفاءة استخدام المياه في نظامي أكوابونيك مغلق الدورة وهيدروبونيك بتقنية الغشاء المغذي *(NFT)*

أحمد شعبان ابديوي[*1]، إبتهال البشير التير[2]
[1] قسم الهندسة الزراعية، كلية الزراعة، جامعة طرابلس، طرابلس، ليبيا
[2] خريج قسم الهندسة الزراعية، كلية الزراعة، جامعة طرابلس، طرابلس، ليبيا

[*]Corresponding author: a.ebdiwy@uot.edu.ly

Received: August 14, 2026	Accepted: October 25, 2026	Published: November 17, 2026

Abstract:

Background and Objective: Renewable freshwater in Libya amounts to under 100 m³ per person annually, one of the smallest figures anywhere in the world (FAO, 2023). Soil is steadily deteriorating and farming leans on fossil groundwater, so conventional agriculture is becoming harder to maintain. Growing crops without soil is a workable alternative, but side-by-side tests of hydroponics and aquaponics on valuable aromatic crops are rare for Libyan conditions. The aims of this work were (i) to design and commission a recirculating aquaponic system combining Koi carp (*Cyprinus carpio* var. *koi*) and sweet basil (*Ocimum basilicum* L.), and (ii) to evaluate it provisionally against a benchmark NFT hydroponic system.

Methods: The trial lasted 42 days in spring 2025 in Tripoli, Libya, with 24 plants per system. For weekly height measurements and the destructive biomass harvest, five plants per system were picked at random. A two-part commercial nutrient solution (Part A and Part B), targeting 800–1,000 ppm EC, fed the NFT system; the aquaponic system got no synthetic nutrients and depended only on fish waste. Eight Koi carp (initial mean weight 85 ± 12 g; stocking density 3.4 kg/m³) received 2% of their body weight daily offered at (09:00 and 16:00 h). The statistical tools were independent-samples t-tests and simple linear regression (IBM SPSS v26; $\alpha = 0.05$). Having only one system per treatment is acknowledged as the chief methodological limitation.

Results: Height was significantly greater in the hydroponic system (78.0 ± 0.08 cm vs. 52.1 ± 0.17 cm; $p < 0.001$). For biomass quality, measured as dry matter and moisture content in every fraction, the systems did not differ significantly ($p > 0.05$), so tissue quality was equivalent even though growth was not. The aquaponic system had a significantly higher pH (6.83 ± 0.29 vs. 6.05 ± 0.24; $p < 0.001$), and water temperature was unaffected (22.4 ± 1.8 vs. 23.1 ± 2.1°C; $p = 0.312$). Evaporative concentration pushed hydroponic TDS above

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

the target, while aquaponic TDS stayed under it because nutrients arose from biological cycling only. Ammonia in the aquaponic system showed a strong positive linear association with plant height ($R^2 = 0.81$, $n = 5$, $p < 0.037$; $y = 290.05x - 62.055$).

Conclusion: Plants grown using the hydroponic system exhibited greater vegetative growth. In contrast, basil plants cultivated via the aquaponic system—which relies on nutrients derived from the biological activity of fish—may face challenges; for instance, a higher pH level in an aquaponic system can reduce the availability and uptake of certain nutrients by the plants. Nevertheless, the aquaponic system remains a promising technical option, offering the potential for efficient nutrient utilization and water recycling, thereby supporting soil-less agricultural systems.

Keywords: Aquaponics; Hydroponics; Nutrient Film Technique; Nitrification; soilless culture; sustainable food systems; Libya.

الملخص:

الخلفية والأهداف: تُعد ليبيا من الدول العالم ندرةً في المياه، إذ يقلّ نصيب الفرد فيها من الموارد المياة الغذبة عن 100 م^3 سنوياً (FAO,2023)، وتتفاقم هذه المشكلة نتيجة ذلك تدهور الترب والاعتماد على المياة الجوفية. تسهم الزراعة بدون تربة في ترشيد استهلاك المياة، إلا أن الدراسات المقارنة بين نظامي الهيدروبونيك (Hydroponic) والأكوابونيك (Aquaponic) في انتاج المحاصيل العطرية في الظروف الليبية ماتزال محدودة. وعلية تهدف الدراسة إلى: (1) تصميم نظام أكوابونيك مغلق الدورة يجمع بين أسماك الكوي (*Cyprinus carpio var. koi*) والريحان الحلو (*Ocimum basilicum L.*) وتشغيله، و(2) إجراء مقارنة أولية لنمو الريحان وجودة كتلته لحيوية وتغيرات نوعية المياه ومقارنتها بنظام هيدروبونيك بتقنية الغشاء المغذي (NFT).

المواد وطرائق البحث: نفدت التجربة واستمرت 42يوماً في ربيع 2025 بمدينة طرابلس، ليبيا، باستخدام 24نباتاً في كل نظام ونظام واحد لكل معاملة. اختيرت خمس نباتات عشوائياً من كل نظام لقياس الارتفاع أسبوعياً. زُود النظام بمحلول مغذً تجاري ثنائي المكونات (AوB) بتركيز موصلية كهربائية (EC) يتراوح بين (800-1000) جزء في المليون (ppm)، بينما لم يُضف إلى نظام الأكوابونيك أي سماد صناعي، واعتُمد فيه على المغذيات الناتجة من الأسماك وحدها. وُضعت ثماني أسماك كوي (متوسط الوزن الابتدائي85±12غ الكتلة الحيوية الكلية 680غ كثافة التخزين 3.4كغ/م^3) في حوض زجاجي سعته 200لتر، غذّيت بمعدل 2% من وزن الجسم يومياً على دفعتين (09:00 و16:00). عُرضت النتائج بصيغة المتوسط± الانحراف المعياري، قورن بين النظامين بالاختبار(t-tests) للعينات المستقلة في كل قياس أسبوعي، والعلاقة بين تركيز الأمونيا في الأكوابونيك وارتفاع النبات بالانحدار الخطي البسيط (الاسابيع1-5،n=5؛ باستخدام برنامج IBM SPSS الإصدار 26؛ عند مستوى دلالة $\alpha = 0.05$).

النتائج: أظهرت النتائج تفوقاً معنوياً في طول النباتات المزروعة بنظام الهيدروبونيك (Hydroponic)مقارنة بنظام الأكوابونيك (Aquaponic) (78.0 ± 0.08 سم مقابل 52.1 ± 0.17 سم؛ $p < 0.001$). أما جودة الكتلة الحيوية، التي قدّرت بناءً على المادة الجافة ومحتوى الرطوبة في جميع أجزاء النبات، لم تظهر فروق معنوية بين النظامين ($p > 0.05$)؛ مما يعني أن جودة الأنسجة كانت متماثلة، على الرغم من اختلاف معدلات النمو. و سجل نظام الأكوابونيك قيمة أعلى معنوياً للرقم الهيدروجيني (pH) (6.83 ± 0.29 مقارنة6.05 ± 0.24؛ $p < 0.001$)، بينما لم تتأثر درجة حرارة الماء معنوياً (22.4 ± 1.8 مقابل 23.1 ± 2.1 درجة مئوية؛ $p = 0.312$). ، أدى التبخر الماء إلى ارتفاع تركيز المواد الصلبة الذائبة (TDS) في نظام (Hydroponic)، بينما نظام الأكوابونيك ضمن التركيز المستهدف؛ ويعزى ذلك إلى اختلاف آليات إمداد العناصر الغذائية بين نظامين. بينما أظهرت تراكيز الأمونيا في نظام (Aquaponic) ارتباطاً خطياً إيجابياً قوياً مع طول النبات ($R^2 = 0.81$، $n = 5$، $p < 0.037$؛ $y = 290.05x - 62.055$).

الخلاصة: النباتات بنظام الهيدروبونيك (Hydroponic) سجلت ارتفاعاً نباتياً أكبر، بينما اظهرت نباتات الريحان المزروعة بنظام الأكوابونيك، والمعتُمدة على العناصر الغذائية الناتجة عن النشاط الحيوي للأسماك، كما قد يسهم ارتفاع الرقم الهيدروجيني في نظام الأكوابونيك في تقليل إتاحة بعض المواد العناصر الغذائية وامتصاصها بواسطة النبات، يُعد نظام الأكوابونيك خياراً تقنياً واعدًا، مما يوفر من إمكانية الاستفادة من المغذيات وإعادة تدوير المياه، بما يدعم نظم الزراعة بدون تربة.

الكلمات المفتاحية: الأكوابونيك (Aquaponics)، الهيدروبونيك (Hydroponics)، تقنية الغشاء المغذي، النترجة، الزراعة بدون تربة، أنظمة غذائية مستدامة.

1. Introduction

Sweet basil (Ocimum basilicum L.) is cultivated worldwide for its essential oils, its use in cooking, and its medicinal properties (Simon et al., 1999). Growing it in Libya and other arid regions is hampered by serious water scarcity, low-quality soils, and rapid evaporation. Annual renewable freshwater in Libya is below 100 m^3 per capita, which makes water supply a leading agricultural problem (FAO, 2023). Fertiliser dependence further

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

raises production costs and worsens soil degradation and environmental stress (Libyan Ministry of Agriculture, 2022). Soilless systems therefore look like a promising path towards sustainable basil production under such conditions.

Under NFT hydroponics, roots are bathed in a constant flow of nutrient-rich solution, and water use falls by more than 90% compared with conventional irrigation (Resh, 2022). Basil usually does well here, growing faster and producing more essential oil than in soil (Saha et al., 2016). The drawback is that NFT relies on synthetic fertilisers, which push up costs and environmental impacts (Goddek et al., 2021).

In aquaponics, fish farming and hydroponics share one recirculating loop. Beneficial bacteria turn the ammonia produced by the fish into nitrate, which plants then absorb as a nutrient (Rakocy et al., 2006). Koi carp (*Cyprinus carpio* var. *koi*) are well suited because their waste provides nutrients and they tolerate changing water conditions (Andrian et al., 2024; Hussain & Brown, 2025). In the present study, fish-derived nutrients were the only source of plant nutrition, and no synthetic fertilisers were used.

Results from earlier aquaponic and hydroponic comparisons vary. Aquaponic systems often give lower yields owing to deficiencies of essential nutrients, especially potassium, calcium, and iron (Delaide et al., 2016; Roosta, 2014). Basil growth and productivity also respond to nutrient concentration, in particular TDS (Yang & Kim, 2020). Fish-waste organic nutrients, however, may improve availability (Yep & Zheng, 2019). Since little work exists on basil in aquaponics, particularly in arid settings, more research is needed (Hussain & Brown, 2025).

The objectives were therefore to: (1) establish a recirculating aquaponic system based on Koi; (2) monitor the vegetative growth of basil over 42 days; (3) evaluate biomass quality; (4) compare water physicochemical properties between the two systems; and (5) investigate how ammonia concentration is related to vegetative growth in the aquaponic system.

2. Materials and Methods

2.1 Experimental Location, Design, and Plant Material

Fieldwork was conducted in spring 2025 in the Arada area of Tripoli, Libya (32°54′N, 13°11′E), in the prevailing natural environment. Two cultivation methods, NFT hydroponics and Koi-based recirculating aquaponics, were compared in a Completely Randomised Design (CRD), each with a single system (n = 1). Lack of replication at system level is an important methodological limitation, and it was kept in mind during analysis and interpretation of the results.

A local aquifer supplied groundwater to both systems, with initial EC, TDS, and pH of 0.65 dS/m, 415 mg/L, and 7.45, respectively. Each system received a total of 24 healthy, uniform sweet basil (*Ocimum basilicum* L.) seedlings, whose roots had been washed with distilled water before transplanting. At the end of the experiment, five plants per treatment, randomly chosen, were used for weekly height monitoring and destructive biomass evaluation.

2.2 System Design and Configuration

2.2.1 Hydroponic System (NFT)

NFT channels were 100 mm PVC pipes laid at a 2% slope, letting the nutrient solution move by gravity. Net pots with pre-moistened LECA were spaced 100 mm apart. A 50 L HDPE tank held the solution, which a 45 W submersible pump circulated for one hour in each 12-hour cycle. Throughout the experiment a commercial two-component nutrient formulation (Part A and Part B) maintained a target concentration of 800–1,000 ppm, and pH was adjusted every day to 5.5–6.5. Average TDS reached 1,419 ± 32.1 ppm, higher than intended; as explained in Section 3, this was linked to evaporation across the 42-day period and to the TDS already contributed by the groundwater (415 mg/L).

2.2.2 Aquaponic System: Design and Commissioning

A 200 L glass fish tank (100 × 50 × 45 cm) formed the core of the aquaponic installation and was connected to an acrylic-supported hydroponic growing bed with 24 planting sites filled with LECA (Figure 1). Eight Koi carp (*Cyprinus carpio* var. *koi*) were stocked in the tank, each initially weighing 85 ± 12 g on average, which gave a total biomass of 680 g and a stocking density of 3.4 kg/m³.

Feeding used a commercial floating pellet feed with 35% crude protein, supplied at a daily rate of 2% of total biomass and divided equally between 09:00 and 16:00 h; the protocol was recorded to enable later nitrogen mass-balance calculations. A 20 W aeration pump kept dissolved oxygen up. No synthetic fertilisers were introduced during the trial, and plants obtained their nutrients exclusively from the mineralisation of fish waste and the nitrification that followed.

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Five filtration components made up the recirculating unit:

1. **Mechanical Filtration:** Removes large solid particles and uneaten feed from the water in circulation.
2. **Sponge Filtration:** Traps smaller suspended particles, preventing them from accumulating in later filtration stages.
3. **Activated Carbon Filtration:** Adsorbs dissolved organic compounds, volatile substances, and the sources of unpleasant odours.
4. **Biological Filtration:** Offers high-surface-area media for *Nitrosomonas* and *Nitrobacter* spp. to grow, and these bacteria oxidise ammonia stepwise to nitrite and nitrate.
5. **UV Sterilisation:** Reduces pathogenic microorganisms and microalgae, which helps keep the water clear and of good quality.

The aquaponic unit ran for 12 days before the basil seedlings were added, allowing microbial activity to become established in the filtration system. Ammonia concentrations rose above the initial baseline, showing that the fish were metabolically active and that nitrification had begun.

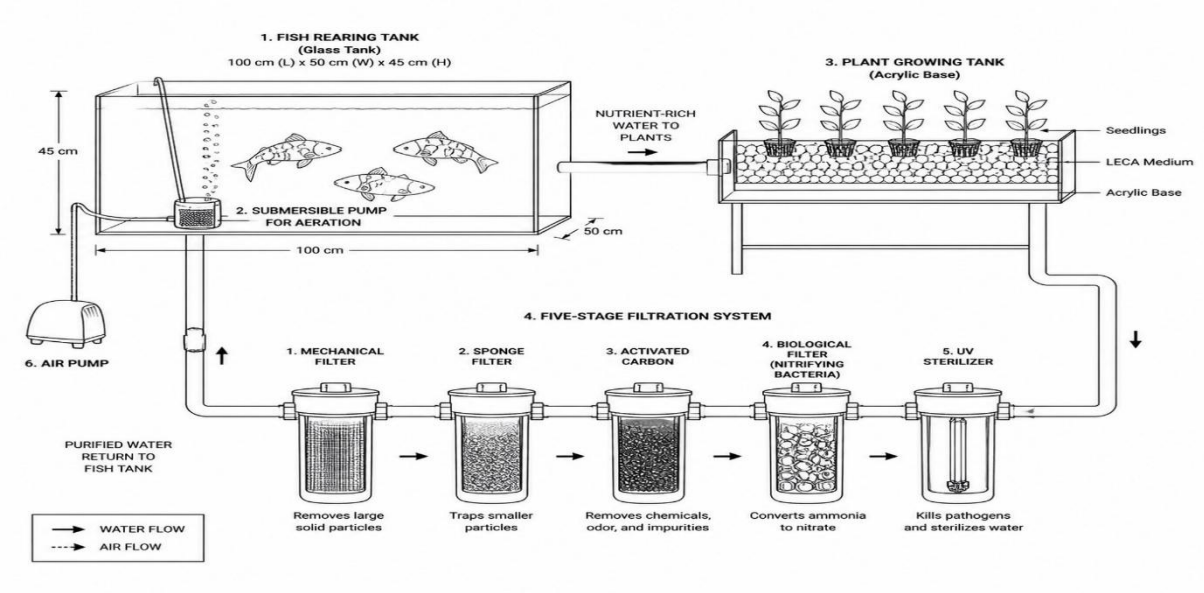


Figure 1. *Diagram of the recirculating Koi-based aquaponic system: (1) glass fish-rearing tank (200 L; 100 × 50 × 45 cm); (2) submersible aeration pump (20 W); (3) LECA plant growing bed on an acrylic base (24 positions); (4) five-stage filtration unit; (6) external air pump. Solid arrows indicate water flow and dashed arrows indicate air flow.*

2.3 Data Collection and Parameter Monitoring

2.3.1 Physicochemical Analysis

In both systems pH and TDS were measured daily with calibrated digital meters, whereas DO and temperature were measured weekly with a HANNA HI9829 multiparameter meter. Only the aquaponic system was tested weekly for NH_3-N, with a portable photometer and standard colorimetric reagents, because ammonia has no real significance in synthetic hydroponic solutions. Reported values are system-level temporal means. Every session began with instrument calibration, and readings were taken between 09:00 and 10:00 h in order to minimise diurnal variation.

Table 1. Measured parameters, instruments, and sampling frequency.

No.	Parameter	Instrument / Method	Frequency
1	pH	Digital pH meter (calibrated, daily buffer check)	Daily
2	TDS (ppm)	TDS/EC meter (calibrated)	Daily
3	Temperature (°C)	HANNA HI9829 Multiparameter Meter	Daily
4	Relative Humidity (%)	Digital hygrometer	Daily
5	DO (mg/L)	HANNA HI9829 Multiparameter Meter	Weekly
6	NH_3-N (mg/L) [AQ only]	Portable photometer, colorimetric reagents	Weekly
7	Plant Height (cm)	Calibrated steel ruler, substrate to apical meristem	Weekly
8	Dry Matter & Moisture (%)	Oven-drying 60°C × 24 h; analytical balance	Post-harvest

AQ = aquaponic; HD = hydroponic. NH_3-N was measured in AQ only. All measurements were taken between 09:00 and 10:00 h local time.

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

2.3.2 Growth and Biomass Evaluation

Each week, the height of the five randomly selected plants in each system was measured from the substrate surface up to the apical meristem (n = 5 per system per week; weeks 1–6). When the trial ended, those five plants were harvested and divided into roots, stems, and leaves. Fresh weight (FW) was taken immediately; the samples were then oven-dried at 60°C for 24 h and reweighed to give dry weight (DW).

$$\mathbf{MC\ (\%) = [(FW - DW) / FW] \times 100 \quad \ldots (Eq.\ 1)}$$

$$\mathbf{DMC\ (\%) = [DW / FW] \times 100 \quad \ldots (Eq.\ 2)}$$

Because MC and DMC are complementary, together they total 100%.

2.4 Statistical Analysis

Results are given as mean ± SD. Independent-samples t-tests compared the two systems at each weekly measurement . Only the aquaponic system was subjected to simple linear regression, which quantified how weekly ammonia concentration related to plant height. The regression used weeks 1–5 only (n = 5), since ammonia could not be sampled in week 6 for logistical reasons at the end of the trial. Explained variance is reported as R^2. The significance level was $\alpha = 0.05$ throughout (IBM SPSS v26.0). With a single system per treatment, individual plant measurements (n = 5) were the unit of analysis, so findings should be considered preliminary until replicated system-level trials are carried out.

3. Results and Discussion

3.1 Vegetative Growth: Plant Height Trajectories

Both systems supported basil growth, but hydroponic plants were taller at every time point ($p < 0.001$; Table 2, Figure 2). At week 6 the hydroponic plants stood at 78.0 ± 0.08 cm compared with 52.1 ± 0.17 cm in the aquaponic system, roughly 50% taller. A gap was already visible in week 1 (6.04 vs. 4.26 cm) and it kept widening, which suggests an ongoing nutrient deficit in the aquaponic system and not just slow recovery from transplanting.

Hydroponic TDS averaged 1,419 ± 32.1 ppm, exceeding the 800–1,000 ppm target, but this was predictable. The source water started at 415 mg/L, and evaporation concentrated the reservoir over six weeks; even so, the system stayed within the broader range recommended for intensive NFT basil production (Jones, 2014). With fish waste as its sole input, the aquaponic system reached just 728 ± 109.2 ppm. A difference of 691 ppm is very likely the cause of the height gap. Delaide et al. (2016), Roosta (2014), and Yang & Kim (2020) all arrive at the same conclusion, namely that nutrient concentration, not system type, determines yield.

Table 2. Mean plant height (cm ± SD) in the aquaponic (AQ) and hydroponic (HD) systems (n = 5 per system).

System	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Aquaponic (AQ)	4.26 ± 0.15	13.3 ± 0.25	23.0 ± 0.12	31.5 ± 0.23	40.4 ± 0.21	52.1 ± 0.17
Hydroponic (HD)	6.04 ± 0.11	20.6 ± 0.11	34.1 ± 0.18	50.7 ± 0.08	64.3 ± 0.25	78.0 ± 0.08
p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Independent-samples t-test; α = 0.05. Every between-system difference had p < 0.001.

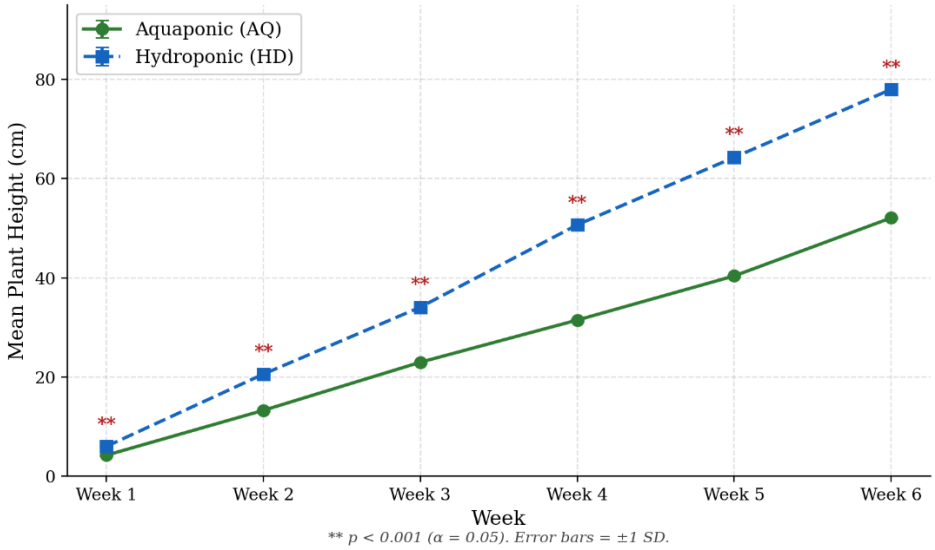


***Figure 2**. Mean weekly plant height (± SD) in the AQ and HD systems over six weeks. Error bars show ± 1 SD. ** p < 0.001 at every time point (α = 0.05).*

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

3.2 Physicochemical Water Quality Parameters

3.2.1 Solution pH

The mean pH in the aquaponic system was 6.83 ± 0.29, significantly above the 6.05 ± 0.24 of the hydroponic system ($p < 0.001$; Table 3). Fish respiration and the biofilm on filter media drive pH upward by way of carbonate alkalinity, a normal behaviour for such systems (Graber & Junge, 2009). Daily buffer adjustment kept hydroponic pH at 6.05. Aquaponic pH was not adjusted; that is realistic for a low-input system, but it carries consequences for micronutrient availability.

Basil prefers a pH of 5.5–6.5, and 6.83 lies above that range. Over 6.5, iron precipitates as ferric hydroxide and phosphorus becomes less soluble (Jones, 2014). Slight leaf pallor seen around week 5 agrees with this; it was visible but too mild to affect the biomass data statistically. Lowering pH is the clearest available lever, as it requires no synthetic nutrients and would regain most of the micronutrient availability lost to alkaline conditions.

3.2.2 Total Dissolved Solids (TDS)

Both systems missed the 800–1,000 ppm target, in opposite directions, and TDS differed significantly between them ($p < 0.001$; Table 3). Hydroponic TDS overshot at 1,419 ppm owing to evaporative concentration over six weeks, made worse by the 415 mg/L baseline in the source water (Resh, 2022). Aquaponic TDS undershot at 728 ppm because fish waste was the only nutrient source. The coefficients of variation reflect this biological variability: 15.0% for aquaponics against 2.3% for hydroponics. The solution is manageable, since adding potassium sulphate, calcium nitrate, and chelated iron would bring TDS into the target range without introducing synthetic fertilisers (Delaide et al., 2016; Yep & Zheng, 2019).

3.2.3 Dissolved Oxygen and Water Temperature

Both systems had adequate dissolved oxygen, 9.30 ± 1.82 mg/L in aquaponics and 10.86 ± 2.45 mg/L in hydroponics, and the difference was not significant ($p = 0.178$; Table 3). These values are above the 6–8 mg/L threshold for nitrification and root respiration (Homoki et al., 2021). Temperature was likewise similar, at 22.4 ± 1.8°C versus 23.1 ± 2.1°C ($p = 0.312$). Neither factor accounts for the yield difference.

Table 3. Physicochemical water quality parameters (mean ± SD) over the 42-day period.

Parameter	Aquaponic (AQ)	Hydroponic (HD)	p-value
pH	6.83 ± 0.29	6.05 ± 0.24	< 0.001*
TDS (ppm)	728 ± 109.2	1,419 ± 32.1	< 0.001*
DO (mg/L)	9.30 ± 1.82	10.86 ± 2.45	0.178 ns
Temperature (°C)	22.4 ± 1.8	23.1 ± 2.1	0.312 ns
NH_3-N (mg/L)	0.29 ± 0.04	N/A	AQ only

** $p < 0.001$; ns = not significant ($\alpha = 0.05$). NH_3-N was measured in the AQ system only. N/A = not applicable. Source water baseline: EC = 0.65 dS/m, TDS = 415 mg/L, pH = 7.45*

3.3 Biomass Quality: Dry Matter and Moisture Content

Although hydroponic plants were taller, their tissue quality matched that of aquaponic plants. Moisture content and dry matter in roots, stems, and leaves showed no significant differences between the systems ($p > 0.05$; Table 4). Dry matter percentages were slightly higher in aquaponic roots and stems (7.9% vs. 5.1%; 9.0% vs. 6.6%), which could reflect a greater investment in structural carbon when nutrients are limited. With $n = 5$, though, these differences lack statistical significance and should not be over-interpreted.

According to Savvas & Gruda (2018), tissue quality is governed more by nutrient bioavailability than by total dissolved concentration. Organic fractions from fish waste appear to be enough to maintain equivalent tissue composition in spite of lower overall TDS, and the data bear this out.

The practical message is clear. Aquaponic growers in Libya cannot yet match hydroponic yields, but the product is identical in quality, with the same dry matter, moisture, and tissue structure. It is market-grade basil produced without synthetic fertiliser, and where markets reward clean, sustainable production, that is a genuine commercial argument.

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Table 4. Dry matter content (DMC) and moisture content (MC) in basil fractions at week 6 (n = 5 per system).

Plant Fraction	AQ MC (%) ± SD	HD MC (%) ± SD	p-value (MC)	AQ DMC (%)	HD DMC (%)	p-value (DMC)
Roots	92.1 ± 3.6	94.9 ± 3.8	0.190 ns	7.9	5.1	0.190 ns
Leaves	91.5 ± 1.1	92.7 ± 2.5	0.282 ns	8.5	7.3	0.282 ns
Stems	91.0 ± 2.1	93.4 ± 3.1	0.130 ns	9.0	6.6	0.130 ns

DMC (%) equals 100 − MC (%). ns = not significant (α = 0.05). Test used: independent-samples t-test.

3.4 Ammonia Concentration and Plant Growth in the Aquaponic System

In the aquaponic system, ammonia and plant height moved closely together over weeks 1–5 ($R^2 = 0.81$, $r = 0.90$, $p < 0.037$, $n = 5$; Figure 3). Ammonia was not collected in week 6 because of logistical constraints at the end of the trial, which is why the regression has five observations. According to the equation $y = 290.05x - 62.055$, each 0.01 mg/L increase in ammonia corresponds to about 2.9 cm of additional height. Concentrations between 0.24 and 0.34 mg/L (mean: 0.29 ± 0.04 mg/L) were sufficient for active nitrification and far below the 0.5 mg/L welfare limit for Koi (Resh, 2022).

With $R^2 = 0.81$, ammonia alone explains most of the week-to-week variation in height; the other 19% comes from additional nutrients, temperature shifts, and differences among plants. Wongkiew et al. (2017) and Savvas & Gruda (2018) observed the same pattern. Practically, ammonia offers a cheap, real-time indicator of the nitrogen being cycled in the system. Raising stocking density or improving biofilter aeration would move more nitrogen around the loop and would probably accelerate plant growth.

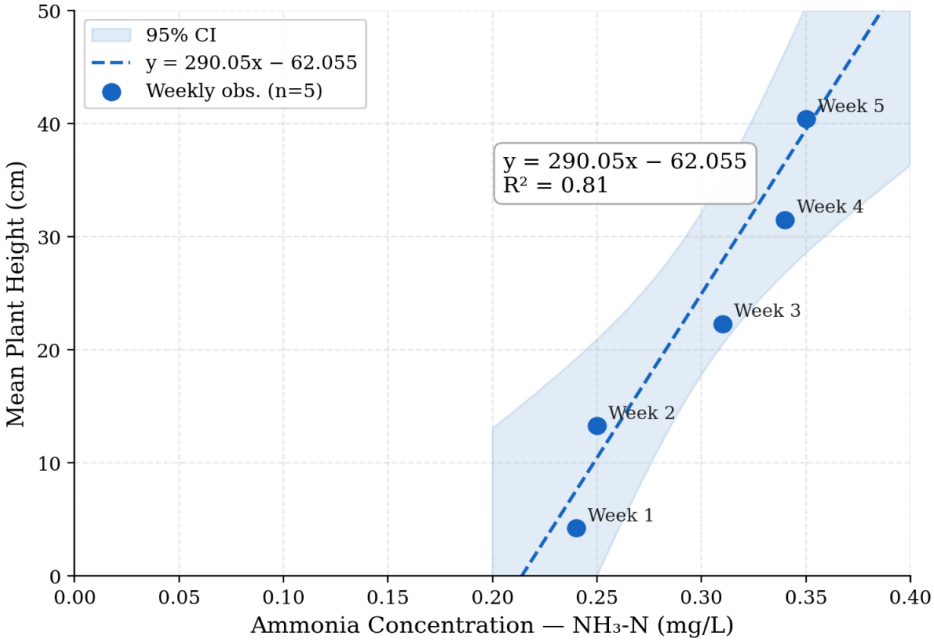


Figure 3. *Linear regression of mean basil height on NH_3-N concentration in the aquaponic system (n = 5, weeks 1–5). $R^2 = 0.81$, $p < 0.001$; $y = 290.05x - 62.055$. The shaded band is the 95% confidence interval. Ammonia was not sampled in week 6; height data for all six weeks appear in Table 2 and Figure 2.*

4. Conclusions

A recirculating Koi-based aquaponic system was built and run alongside an NFT hydroponic system for 42 days in Tripoli, and its effect on basil was measured. The principal findings were:

1. Plants grew significantly taller under hydroponics (78.0 vs. 52.1 cm; $p < 0.001$), This difference coincided with higher TDS levels in the hydroponic system, potentially reflecting synthetic nutrient addition and evaporative concentration.
2. Without any synthetic inputs, the aquaponic system still gave basil of no statistically significant differences in the measured tissue-quality parameters ($p > 0.05$); fish-derived nutrients sufficed to support equivalent dry matter and moisture composition.
3. The 800–1,000 ppm TDS target was missed by both systems, for opposite reasons. Nutrient analysis is required to identify specific deficiencies before applying targeted mineral supplementation

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

4. A strong link between ammonia and height ($R^2 = 0.81$, $p < 0.037$; $y = 290.05x - 62.055$) suggests a strong association between nitrogen dynamics and plant growth, although further investigation is required to clarify the role of nitrification.
5. Equivalent biomass quality achieved without synthetic fertiliser highlights the potential of aquaponics to reduce reliance on synthetic nutrient inputs and promote resource-efficient production.
6. In spite of minor limitations from the elevated pH (6.83) ،closed-loop aquaponics produced basil with comparable values for the measured tissue-quality parameters, which makes it a viable and water-smart choice for Libyan agriculture.

5. Recommendations

1. Analyze nutrient concentrations in the aquaponic water and apply targeted supplementation with potassium sulphate, calcium nitrate, and chelated iron, where deficiencies are identified, to improve nutrient balance and support plant growth.
2. Apply active pH control (CO_2 injection or dilute acid dosing) to keep aquaponic pH at 6.0–6.5 and improve the availability of iron and phosphorus.
3. Increase fish stocking density and feed loading, staying within welfare limits, to raise nitrogen throughput, as the $R^2 = 0.81$ ammonia–height relationship supports.
4. Conduct replicated trials, with at least three systems per treatment and a standardised fish-to-plant ratio, lasting no less than 12 weeks and covering several seasons, so that statistically definitive data can be obtained.
5. Install automated pH dosing, DO alarms, and temperature control to limit physicochemical variability, above all in the aquaponic system.
6. Carry out a techno-economic assessment for Libyan market conditions, including capital costs, water and energy use per unit of yield, and combined revenue from fish and herbs.
7. Trial other crops such as mint, parsley, lettuce, and rocket to determine where input-independent aquaponics is most competitive commercially.
8. Characterise basil quality attributes, namely essential oil composition, antioxidant capacity, chlorophyll content, and mineral profile, in order to quantify quality premiums that could support market differentiation.

Ethical Statement

Institutional animal welfare guidelines were followed in keeping all fish (*Cyprinus carpio* var. *koi*). Water quality was monitored daily, dissolved oxygen never dropped below 6 mg/L, and stocking density remained at 3.4 kg/m³. No ethical approval was needed, as the fish simply provided the biological nutrient source in a standard aquaponic setup.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

References

Andrian, K. N., Wihadmadyatami, H., Wijayanti, N., Karnati, S., & Haryanto, A. (2024). A comprehensive review of current practices, challenges, and future perspectives in Koi fish (Cyprinus carpio var. koi) cultivation. Veterinary World, 17(8), 1846–1860. https://doi.org/10.14202/vetworld.2024.1846

Delaide, B., Goddek, S., Gott, J., Soyeurt, H., & Jijakli, M. H. (2016). Lettuce (Lactuca sativa L.) growth performance in complemented aquaponic solution outperforms hydroponics. Water, 8(10), 467. https://doi.org/10.3390/w8100467

FAO. (2023). AQUASTAT Database – Water resources by country. Food and Agriculture Organization of the United Nations, Rome. https://www.fao.org/aquastat

Goddek, S., Joyce, A., Kotzen, B., & Burnell, G. (Eds.). (2021). Aquaponics food production systems. Springer Nature. https://doi.org/10.1007/978-3-030-15943-6

Graber, A., & Junge, R. (2009). Aquaponic systems: Nutrient recycling from fish wastewater by vegetable production. Desalination, 246(1–3), 147–156. https://doi.org/10.1016/j.desal.2008.03.048

Homoki, D., Odunayo, T., Minya, D., Kovacs, L., Lelesz, J., Barsony, P., Feher, M., Kovics, G., & Stundl, L. (2021). The effect of dissolved oxygen on common carp (Cyprinus carpio) and basil (Ocimum basilicum) in the aquaponics system. Acta Agraria Debreceniensis, 2021(1), 89–96. https://doi.org/10.34101/actaagrar/1/8527

Hussain, A. S., & Brown, P. B. (2025). Current status of the propagation of basil in aquaponic systems: A literature review. Aquaculture Research, 2025(1), 1320019. https://doi.org/10.1155/are/1320019

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Jones, J. B. (2014). Hydroponics: A practical guide for the soilless grower (2nd ed.). CRC Press. https://doi.org/10.1201/9780203473832

Knaus, U., Pribbernow, M., Xu, L., Appelbaum, S., & Palm, H. W. (2020). Basil (Ocimum basilicum) cultivation in decoupled aquaponics and African catfish production in northern Germany. Sustainability, 12(20), 8745. https://doi.org/10.3390/su12208745

Libyan Ministry of Agriculture. (2022). Annual report on agricultural production in Libya. Ministry of Agriculture, Animal Wealth and Fisheries, Tripoli.

Rakocy, J. E., Masser, M. P., & Losordo, T. M. (2006). Recirculating aquaculture tank production systems: Aquaponics — Integrating fish and plant culture (SRAC Publication No. 454). Southern Regional Aquaculture Center.

Resh, H. M. (2022). Hydroponic food production (8th ed.). CRC Press. https://doi.org/10.1201/9781003048350

Roosta, H. R. (2014). Comparison of vegetative growth and mineral nutrient content of basil in hydroponic vs. aquaponic solutions. Journal of Plant Nutrition, 37(12), 1782–1803. https://doi.org/10.1080/01904167.2014.890220

Saha, S., Monroe, A., & Day, M. R. (2016). Growth, yield, plant quality and nutrition of basil under hydroponic systems. Horticulturae, 2(3), 12. https://doi.org/10.3390/horticulturae2030012

Savvas, D., & Gruda, N. (2018). Application of soilless culture technologies in the modern greenhouse industry — A review. European Journal of Horticultural Science, 83(5), 280–293. https://doi.org/10.17660/eJHS.2018/83.5.2

Simon, J. E., Morales, M. R., Phippen, W. B., Vieira, R. F., & Hao, Z. (1999). Basil: A source of aroma compounds and a popular culinary herb. In J. Janick (Ed.), Perspectives on new crops and new uses (pp. 499–505). ASHS Press.

Wongkiew, S., Hu, Z., Chandran, K., Lee, J. W., & Khanal, S. K. (2017). Nitrogen transformations in aquaponic systems: A review. Aquacultural Engineering, 76, 9–19. https://doi.org/10.1016/j.aquaeng.2017.01.004

Yang, T., & Kim, H. J. (2020). Comparisons of nitrogen and phosphorus mass balance for tomato-, basil-, and lettuce-based aquaponic and hydroponic systems. Water, 12(5), 1259. https://doi.org/10.3390/W12051259

Yep, B., & Zheng, Y. (2019). Aquaponic trends and challenges — A review. Journal of Cleaner Production, 228, 1586–1599. https://doi.org/10.1016/j.jclepro.2019.04.290

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of **AJAPAS** and/or the editor(s). **AJAPAS** and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).