Spinach in Hydroponics

Spinach (*Spinacia oleracea*) is one of the **best leafy greens** for hydroponics. It grows quickly, is nutrient-rich, and thrives in **cooler hydroponic conditions** compared to crops like lettuce or basil. Since spinach is sensitive to heat and water stress in soil, hydroponics helps maintain consistent growth.

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1. Hydroponic Systems for Spinach

Spinach grows well in several systems, but the most efficient are:

- **NFT (Nutrient Film Technique):** A thin film of nutrient solution flows over the roots, making it ideal for growing leafy greens.
- **DWC (Deep Water Culture):** Plants float on nutrient solution → simple and effective.
- **Aeroponics (advanced):** Roots are misted → faster growth but costlier.
- For beginners: **DWC or NFT** is easiest.

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2. Growing Medium (for germination & support)

1. Seed Pre-treatment

- **Reason**: Spinach seeds have a hard coat & irregular germination.
- **Steps**: Select high-quality seeds (fresh, disease-free).

1. **Soak in clean water** for **12–24 hours** (room temp ~25 °C
2. Change water once if soaking >12 hrs.3
3. Optionally, disinfect with: **1% Hydrogen peroxide (H_2O_2)** solution for **5 min** reduces fungus.
4. Drain and sow immediately into prepared medium.

2. Growing Medium

A. Rockwool Cubes (Best for NFT)

Use 1″ or 1.5″ cubes.

- **Preparation**: Soak cubes in **pH-adjusted water (5.5–5.8)** for **30 min**.
- Gently shake off excess water (don’t squeeze).

Sowing:

- Place 1–2 soaked seeds in each cube hole.
- Cover lightly with a thin layer of **vermiculite or rockwool flakes**.

Environment:

- Keep cubes in a germination tray, cover with humidity dome or plastic sheet.
- Maintain **air temp 18–22 °C**, **RH 70–80%**, darkness until sprouting.

B. Coco Peat + Perlite Mix (Alternative)

- **Ratio**: 70% Coco Peat : 30% Perlite
- Use 60:40 in very humid climates for better drainage.

Preparation:

- Wash & buffer coco peat (target EC < 0.5, pH ~6).

Sowing:

- Fill seedling trays or net pots with mix.
- Sow 2–3 seeds per cell/net pot → thin later.
- Keep moist but not soggy.

C. Clay Pebbles (LECA)

Not recommended for direct germination → dries quickly.

Germinate in rockwool or coco mix first.

After 2–3 true leaves, **transplant seedlings into net pots with 100% LECA**.

Pre-soak LECA overnight & rinse to remove dust/pH swings.

D. Vermiculite

High water retention → great for germination but risky alone.

Best Mix: 50% Vermiculite : 50% Perlite.

Good alternative if rockwool is not available.

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4. Transplanting to NFT

Timing: **2–3 true leaves + visible root growth (10–14 days old)**.

Method:

1. Place seedlings (with rockwool or coco plug) into **net pots with LECA**.
2. Ensure roots touch the NFT film flow.

Table No.1 Environmental Requirements

Spinach is **sensitive to heat** → bolting (premature flowering) happens if temp > 26°C.

Parameter	Ideal Range	Notes
pH	5.8 – 6.5	Keep stable; check regularly
EC (Electrical Conductivity)	1.8 – 2.3 mS/cm	Too high causes tip burn
Water Temp	18 – 22°C	Cooler water improves growth
Air Temp	15 – 24°C	Prefers cool climate
Humidity	50 – 70%	Too high = fungal risk
Light	10–12 hours/day	150–250 μmol/m²/s (LED or sunlight)

Nutrient Management for Spinach in NFT

1. Nutrient Needs by Growth Stage

Table No. 2.1 Spinach has 3 growth phases in NFT:

Stage	Duration	Nutrient Focus	EC Range
Seedling	0–2 weeks	Lower nutrients, gentle solution	1.0 – 1.4 mS/cm
Vegetative (Leaf Expansion)	2–5 weeks	High nitrogen + calcium	1.6 – 2.0 mS/cm
Mature (Harvest)	5+ weeks	Balanced N, K, Ca	1.8 – 2.3 mS/cm

2. Table No. 2.2 (Macronutrient Requirements (Ideal Ratios in Solution)

Nutrient	Concentration (ppm)	Role
Nitrogen (N)	150–200 ppm	Leaf growth, chlorophyll
Phosphorus (P)	40–60 ppm	Root development
Potassium (K)	200–250 ppm	Leaf thickness, disease resistance
Calcium (Ca)	120–150 ppm	Prevents tip burn
Magnesium (Mg)	40–60 ppm	Chlorophyll synthesis
Sulfur (S)	60–80 ppm	Protein formation

3. Table No. 2.3 Micronutrient Requirements

Micronutrient	Concentration (ppm)	Importance
Iron (Fe)	2–3 ppm	Prevents chlorosis
Manganese (Mn)	0.5–1 ppm	Enzyme activity
Zinc (Zn)	0.05–0.1 ppm	Growth hormone regulation
Copper (Cu)	0.05 ppm	Enzyme systems
Boron (B)	0.5 ppm	Root & leaf health
Molybdenum (Mo)	0.05 ppm	Nitrate utilization

Spinach NFT Nutrient Sources (Water-Soluble)

1. Macronutrients (Table No.3)

2.

Nutrient	Target (ppm)	Fertilizer Source (Water-Soluble)
Nitrogen (N)	150–200	Calcium Nitrate ($Ca(NO_3)_2$) Potassium Nitrate (KNO_3)
Phosphorus (P)	40–60	Mono Potassium Phosphate (KH_2PO_4 / MKP) Phosphoric Acid (H_3PO_4)
Potassium (K)	200–250	Potassium Nitrate (KNO_3) Mono Potassium Phosphate (KH_2PO_4) Potassium Sulfate (K_2SO_4, SOP)
Calcium (Ca)	120–150	Calcium Nitrate ($Ca(NO_3)_2$)
Magnesium (Mg)	40–60	Magnesium Sulfate ($MgSO_4{\cdot}7H_2O$, Epsom Salt) Magnesium EDTA
Sulfur (S)	60–80	Magnesium Sulfate ($MgSO_4{\cdot}7H_2O$) Potassium Sulfate (K_2SO_4)

Micronutrients (Table No.3.1)

Nutrient	Target (ppm)	Fertilizer Source (Water-Soluble)
Iron (Fe)	2–3	**Iron DTPA (Fe-DTPA)** **Iron EDDHA (Fe-EDDHA)**
Manganese (Mn)	0.5–1	**Manganese Sulfate ($MnSO_4{\cdot}H_2O$)**
Zinc (Zn)	0.05–0.1	**Zinc Sulfate ($ZnSO_4{\cdot}7H_2O$)**
Copper (Cu)	0.05	**Copper Sulfate ($CuSO_4{\cdot}5H_2O$)**
Boron (B)	0.5	**Boric Acid (H_3BO_3)**
Molybdenum (Mo)	0.05	**Sodium Molybdate ($Na_2MoO_4{\cdot}2H_2O$)** **Ammonium Molybdate ($(NH_4)_6Mo_7O_{24}{\cdot}4H_2O$)**

- **pH Adjustment**
  - **Phosphoric Acid (H_3PO_4)** → lowers pH, adds phosphorus
  - **Nitric Acid (HNO_3)** → lowers pH, adds nitrate N
  - **Potassium Hydroxide (KOH)** → raises pH, adds potassium

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Step 1: Fix target ppm values (choosing mid-points)

N = 162 ppm

P = 50 ppm

K = 230 ppm

Ca = 140 ppm

Mg = 50 ppm

S = 70 ppm

Fe = 2.5 ppm

Mn = 0.8 ppm

Zn = 0.08 ppm

Cu = 0.05 ppm

B = 0.5 ppm

Mo = 0.05 ppm

Link of Nutrient Source for spinach :

https://docs.google.com/spreadsheets/d/1CTro8F0Xd_hEo-F-R8J4y7tuVKiIoXRuphJnr3RTDwU/edit?usp=drivesdk

Table No.4 Nutrient Composition of Different Fertiizer Sources

		Macronutrients						**Micronutrients**					
Nutrient	**Fertilizer source**	**N**	**P**	**K**	**ca**	**mg**	**S**	**Fe**	**Mn**	**Zn**	**Cu**	**B**	**Mo**
1 .Nitrogen	13:00:45	13%		45 %									
	Calcium Nitrate	15.50%			19 %								
	Urea	46 %											
2.Phosphorus	0:52:34		52 %	34 %									
3.Potassium	13:00:45	13%		45 %									
	0:00:50			50 %			17.5%						
4. calcium	Calcium nitrate	15.50%			19 %								
5. magnesium	Magnesium sulfate					9.5 %	12 %						
	magnesium EDTA					10%							
	Magnesium sulfate					**9.5%**	**12 %**						

6. Sulfur

	Potassium sulfate						17.5%						
7. Micronutrients	**Micronutrients (EDTA) mix**							**2.50 %**	**1.00 %**	**3.00 %**	**1.0 %**	**0.50 %**	**0.10 %**

Method 1 -

Sr. No.	**Fertilizer**	**1 L**	**20 L**
1	Calcium nitrate — $Ca(NO_3)_2$	0.736 g	14.720 g
2	13:00:45 (KNO_3)	0.507 g	10.140 g
3	KH_2PO_4 (mono-K phosphate) 00:52:34	0.096 g	1.920 g
4	00:00:50 K_2SO_4 / 0-0-50	0.303 g	6.060 g
5	$MgSO_4$	0.526 g	10.520 g
6	Micronutrient mix (EDTA; Fe)	0.1 mL	2.0 mL

- **Calcium Nitrate (N= 15.5 %, Ca = 19%)**

1. Calculation for calcium (Ca - 19%)

= 140 × 100 / 19 = 736 mg
To Convert mg/L = 736/1000 = 0.736 g/L
For 20 L Water = 0.736 × 20 =**14.72 g**
= 14.72 g *(Ca Requirement Competed)*

Nitrogen :

= 736 × 15.5 N / 100 = 114.08
(162 - 114.08 = 47.92 ppm N need to Complete n source)

2. 00:52:34 (Phosphorus) KH2PO4

P = 50 × 100 / 52 = 96.15 mg/L
=0.0961 g/L
= 96.15 × 20 L= 1923 mg →1.923 g
K = 96.15 × 34 k / 100 = 32.691 mg/L
(K = 230 ppm - 32.691= 197.31 need to complete k requirement)

3. 13:00:45 potassium

Nitrogen = 47.92 N need × 100 / 13 = 368.615 mg →0.3676 g/L
= 368.615 × 20 = 7372.30 mg → **7.372 gram**
(Nitrogen Requirement completed)
Potassium = 368.6. × 45 k / 100 = 165.8 mg/L
(197.31 - 165.9 = 31.41 K Need)

4. 00:00:50 (To complete k)

= 31.41 × 100 / 50 = 62.82 mg/L
= 62.82 mg/L→0.0564 g/L
(Potassium Requirement Completed)

5. Magnesium Sulphate (MgSO4 , Mg =9.5% ,S12 %)

50 × 100 / 9.5= 526.31 mg L → 0.52631 g
0.52631 g × 20 = **10.526 g**

Sulfur (S= 12 %)

= 526.31 × 12 / 100 = **63.15 g**

We used Micronutrients (EDTA) mix for micronutrient supply:

Fe = 2.5 × 100 /2.5 =100× 200 L , 20000 mg → 20 ml

Calculation for if we used Urea as N source

if we add urea (46% N), then what should be replaced and what else needs to be adjusted.

Therefore, replacing **KNO_3** with urea makes the most sense — since KNO_3 supplies both N and K, while urea supplies only N. The missing K can then be supplied from another K source (K_2SO_4).

6. Calculation for calcium (Ca - 19%)

= 140 × 100 / 19 = 736 mg

To Convert mg/L = 736/1000 = 0.736 g/L

For 20 L Water = 0.736 × 20 =**14.72 g**

= 14.72 g *(Ca Requirement Competed)*

Nitrogen :

= 736 × 15.5 N / 100 = 114.08

(162 - 114.08 = 47.92 ppm N need to Complete n source)

Urea required (to supply 47.92 ppm N):

urea(mg/L = 47.92 × 100 / 46 = 104.174mg/L

For 20 L:104.174 mg /lL×20 = **2.0835 g urea**

K deficit from removing KNO_3 = 45.69 ppm K.

K_2SO_4 provides 50% K, so:

K_2SO_4 (mg/L) = 31.41 × 100 / 50 k = 62.82 mg/L

For 20 L= 62.82 × 20 = 1256.4 mg/L →1.256 g

So new K_2SO_4 total = original 60.64 g + 1.256 g = 61**.89 g**

Table 5: Final Fertilizer Requirement (urea fully replacing KNO_3)

Sr.	Fertilizer (common name / analysis)	1 L	20 L
1	Calcium nitrate — $Ca(NO_3)_2$	**0.736 g**	**14.720 g**
2	KH_2PO_4 (mono-K phosphate)	**0.096 g**	**1.920 g**
3	Urea (46% N)	**0.104174 g** (≈0.104 g)	**2.083 g**
4	K_2SO_4 (0-0-50 style K source)	**0.395 g**	**7.900 g**
5	$MgSO_4$ (Epsom salt)	**0.526 g**	**10.520 g**
6	Micronutrient mix (EDTA; Fe)	**0.1 mL**	**2.0 mL**

Nutrient Deficiencies in Hydroponic Spinach

Nutrient	Deficiency Symptoms	Why It Happens	Corrective Action
Nitrogen (N)	Pale/light green leaves, slow growth, older leaves yellow first	Low N in solution or low EC	Increase nitrate-N ($Ca(NO_3)_2$ / KNO_3), avoid ammonium
Phosphorus (P)	Stunted plants, dark green/purple lower leaves, slow root growth	pH > 6.5 or low P	Add MKP (KH_2PO_4), adjust pH to 5.8–6.2

Nutrient	Deficiency Symptoms	Why It Happens	Corrective Action
Potassium (K)	Leaf edge burn, curling, interveinal yellowing, weak stems	High Ca/Mg competing with K	Add KNO_3 / MKP, reduce excess Ca
Calcium (Ca)	Tip burn (young leaves), necrosis, deformed new growth	Poor Ca mobility, high humidity, fast growth	Add $Ca(NO_3)_2$, improve airflow, avoid excess K/Mg
Magnesium (Mg)	Interveinal chlorosis (yellow between veins) in older leaves	High K or Ca blocking Mg	Add $MgSO_4$ (Epsom salt), adjust K:Mg ratio
Sulfur (S)	Uniform yellowing of young leaves (similar to N, but starts in new leaves)	Very low S in stock mix	Add $MgSO_4$ or K_2SO_4
Iron (Fe)	Yellowing of new leaves, veins remain green (interveinal chlorosis)	High pH (>6.5) blocks Fe	Add Fe chelate (EDDHA/DTPA), keep pH ~5.8–6.2
Manganese (Mn)	Interveinal chlorosis with small brown spots, starting in young leaves	High pH or excess Fe	Add $MnSO_4$, balance Fe/Mn
Boron (B)	Distorted, brittle new leaves, hollow petioles, poor root growth	Low B in solution, high Ca antagonism	Add Borax or Solubor (very small dose)
Zinc (Zn)	Small leaves, shortened internodes, interveinal chlorosis	High pH or high P antagonism	Add $ZnSO_4$ (tiny dose), maintain pH
Copper (Cu)	Wilting, twisted leaves, necrotic tips	Rare in hydroponics	Add Cu chelate (very low ppm)
Molybdenum (Mo)	Pale leaves, similar to N deficiency, edges scorch	Needed for nitrate reduction	Add sodium molybdate / ammonium molybdate