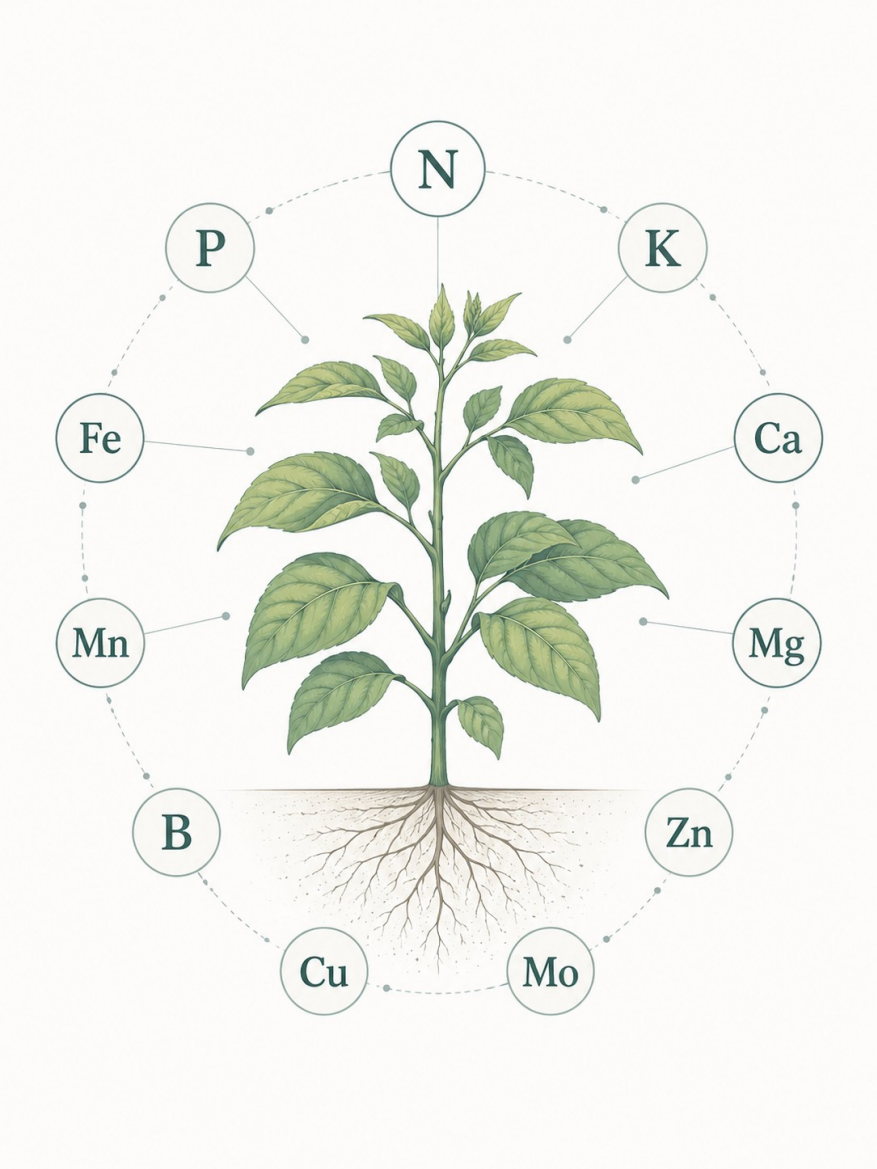
CANNABIS NUTRIENT DISORDERS & DIFFERENTIAL DIAGNOSIS

by Seymore Budz



A citation-led handbook for soilless and controlled-environment production

Literature reviewed through 6 August 2026 | Version 1.1

Purpose and scope

A diagnostic handbook, not a prescription engine

This handbook converts a wide spreadsheet-style diagnostic matrix into a reader-first reference. It is built around controlled cannabis nutrient-omission studies, nutrient dose-response experiments, flowering and environmental trials, tissue-survey work, and disease reviews. The underlying source matrix organised 24 deficiencies, toxicities, functional disorders and flowering differentials; that structure is retained but all unrelated comparison fields have been removed. [1,2,5,7,8,9,10,12,16,18,25,27]

The handbook does not treat visual symptoms as proof. Colour, pattern and canopy position are used to prioritise hypotheses; confirmation depends on root-zone pH and EC, water and nutrient-solution composition, roots, environment, tissue analysis and the timing of symptom progression. [1,2,15,18,27,30,31]

> **Core rule**
>
> Symptoms are clues. Measurements establish cause. Do not change the nutrient programme merely because a photograph appears to match. [1,2,27,30]

What is included

- Rapid triage by first-affected tissue and visual pattern. [1,2,30]
- Twelve essential-nutrient deficiency profiles, including symptom-onset tissue values where a controlled study reported them. [1,2]
- Direct over-supply and antagonism evidence for N, ammonium, K, Mg, P, B, Mn and total root-zone concentration. [1,8,9,10,11,12,18]
- Environmental, root-zone and biological mimics that can resemble nutritional disorders or delay flowering. [15,22,23,25,26,27,28,29]
- Sampling, confirmation and record templates designed to protect controlled experiments from symptom chasing. [1,2,3,4,31]

What is not claimed

- No tissue value is presented as a universal cannabis sufficiency or toxicity threshold. [1,2,3,4]
- No substrate-pH experiment is converted into a universal hydroponic solution-pH prescription. [15,30]
- No single VPD, RH, EC, NPK or cation ratio is presented as universally optimal across cultivars and systems. [5,8,16,18,19,25,26]
- There is still no convincing dedicated modern cannabis calcium dose-response establishing a universal calcium optimum. [1,2,30]

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1. Evidence method and research programmes

Every substantive claim is linked to a source

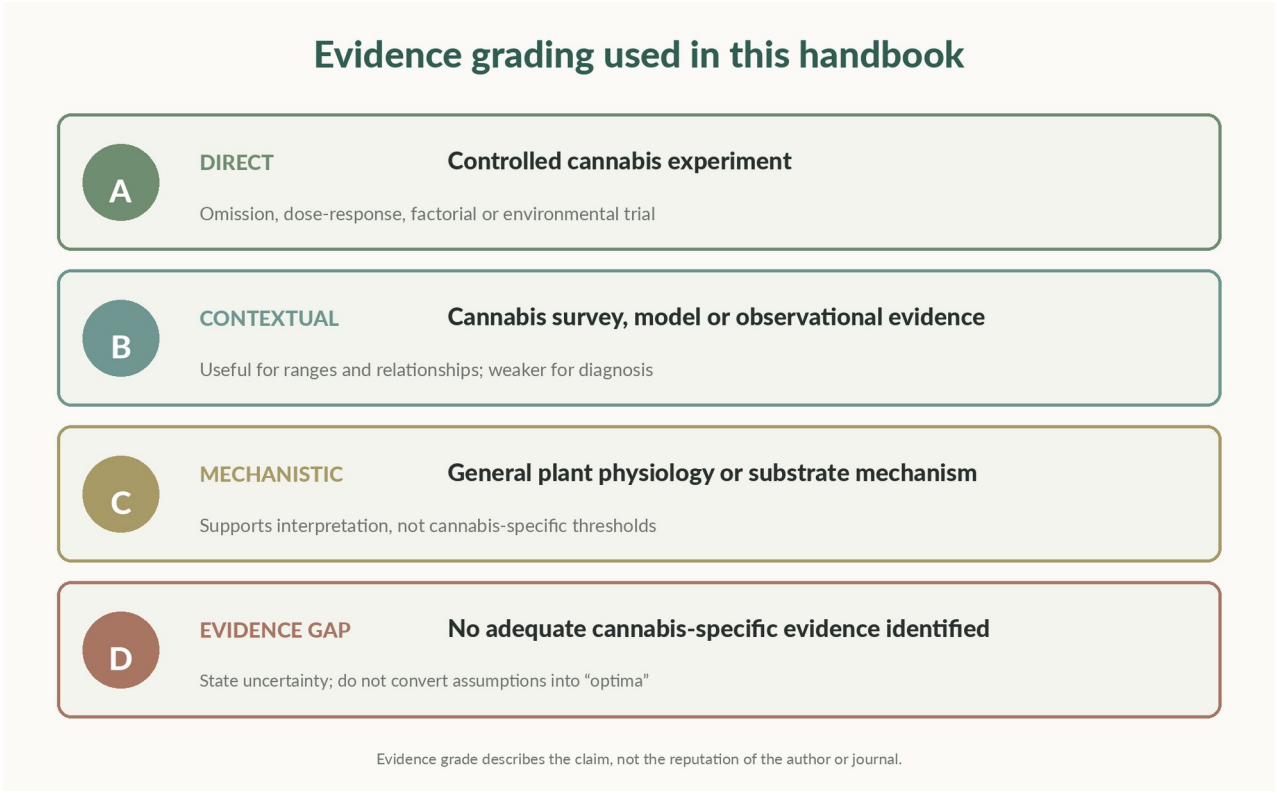


Figure 1. Evidence grading used throughout the handbook. The grade applies to the specific claim, not the reputation of an author or journal. [1,2,5,15,18,25]

Evidence grades

Grade	Meaning
A - direct	Controlled cannabis omission, dose-response, factorial or environmental experiment. Highest weight for the condition actually tested.
B - contextual	Cannabis survey, response-surface model, observational evidence or cross-study synthesis. Useful for context but not a universal diagnostic threshold.
C - mechanistic	General plant physiology, substrate chemistry or transport mechanism used to interpret a cannabis observation.
D - evidence gap	No adequate cannabis-specific evidence identified through 6 August 2026. The handbook states the uncertainty instead of filling it with folklore.

How the author network was expanded

Research programme	Contribution	Key sources
Cockson / Whipker / NCSU	Controlled omission phenotyping, tissue surveys, phosphorus, magnesium, substrate pH and practical diagnostic translation.	[1,3,4,13,14,15]
Bernstein / Volcani Institute	Direct N, P, K, Mg, Zn and nitrogen-form dose responses across vegetative and reproductive stages.	[5,6,7,8,9,10,11,12,35,36]
Zheng / University of Guelph	Flowering-stage deficiency phenotyping, NPK response surfaces, photoperiod and light-intensity experiments.	[2,16,22,23,33,34]

Research programme	Contribution	Key sources
Bugbee / Utah State University	Root-zone phosphorus, nutrient concentration, leachate, luxury uptake and recirculating-system interpretation.	[17,18,31]
Punja / Simon Fraser University	Root, crown, foliar, inflorescence and viroid differentials that can mimic nutritional decline.	[27,28,29]
Additional modern studies	Vegetative NPK response surfaces, clone-specific N response, DLI, RH and temperature effects.	[19,20,24,25,26,37]

Interpretation discipline

A dose-response result applies directly to the tested cultivar, stage, solution, substrate or hydroponic system and environment. Transfer to a different system is an inference that must be labelled and tested. [5,7,8,10,12,16,18,19,25,26]

2. Diagnostic foundations

Location, pattern, progression and measurement

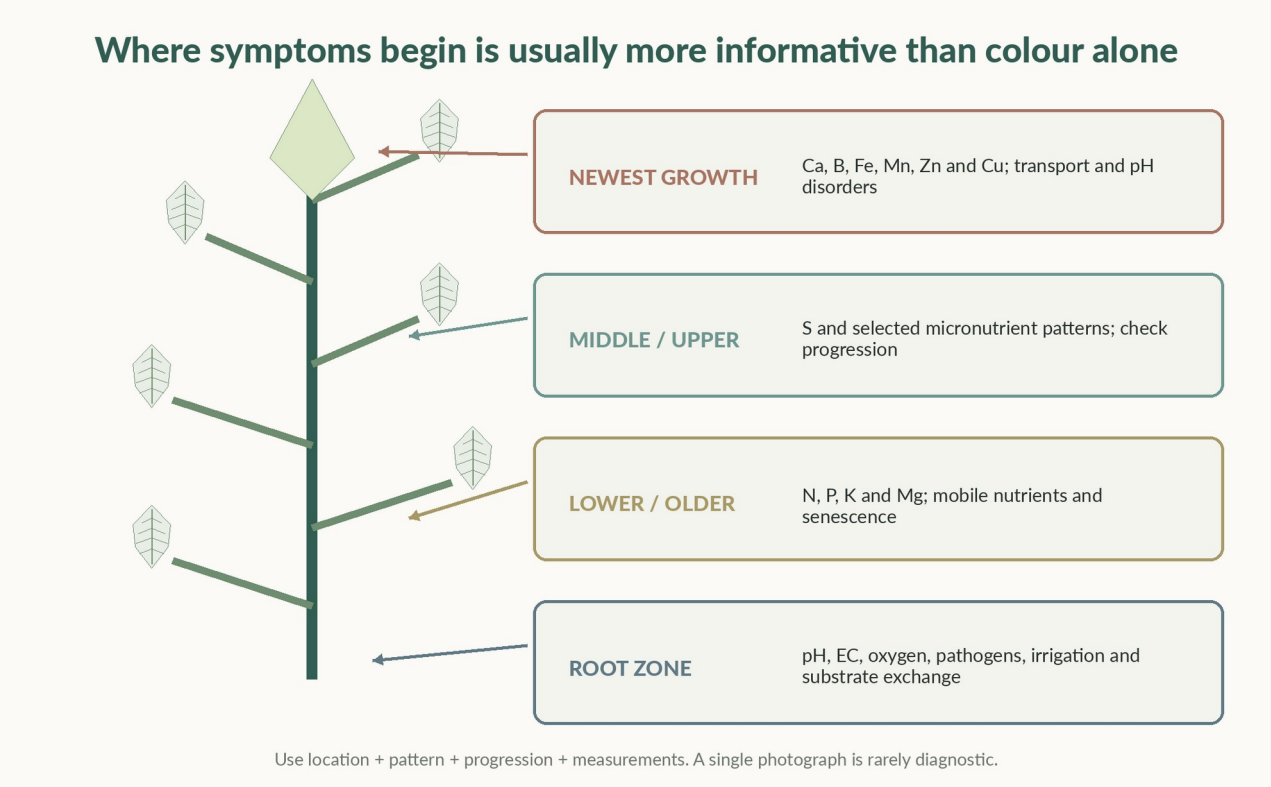


Figure 2. First-affected tissue is usually more informative than colour alone. [1,2,30]

Four observations to make before naming a disorder

1. Location: newest leaves, middle canopy, oldest leaves, meristem, roots or entire plant. [1,2,30]
2. Pattern: uniform chlorosis, interveinal chlorosis, marginal scorch, spots/lesions, distortion or meristem loss. [1,2]
3. Progression: rate, direction through the canopy, relationship to a dosing or irrigation event, and whether new growth is affected. [1,2,27]
4. Distribution: one plant, one irrigation zone, one cultivar, a light gradient, an environmental edge or the full crop. [2,27,29]

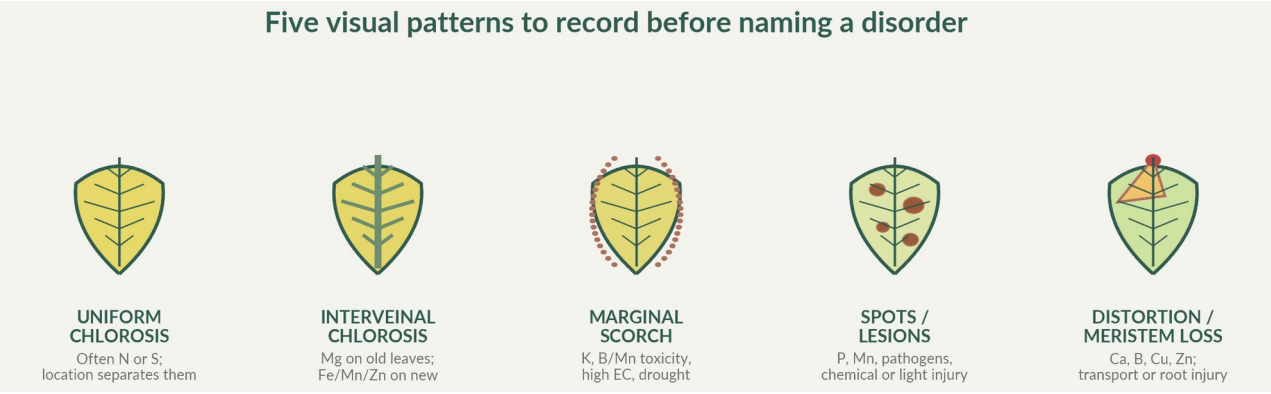


Figure 3. Five patterns to record before assigning a nutrient or system cause. [1,2,27]

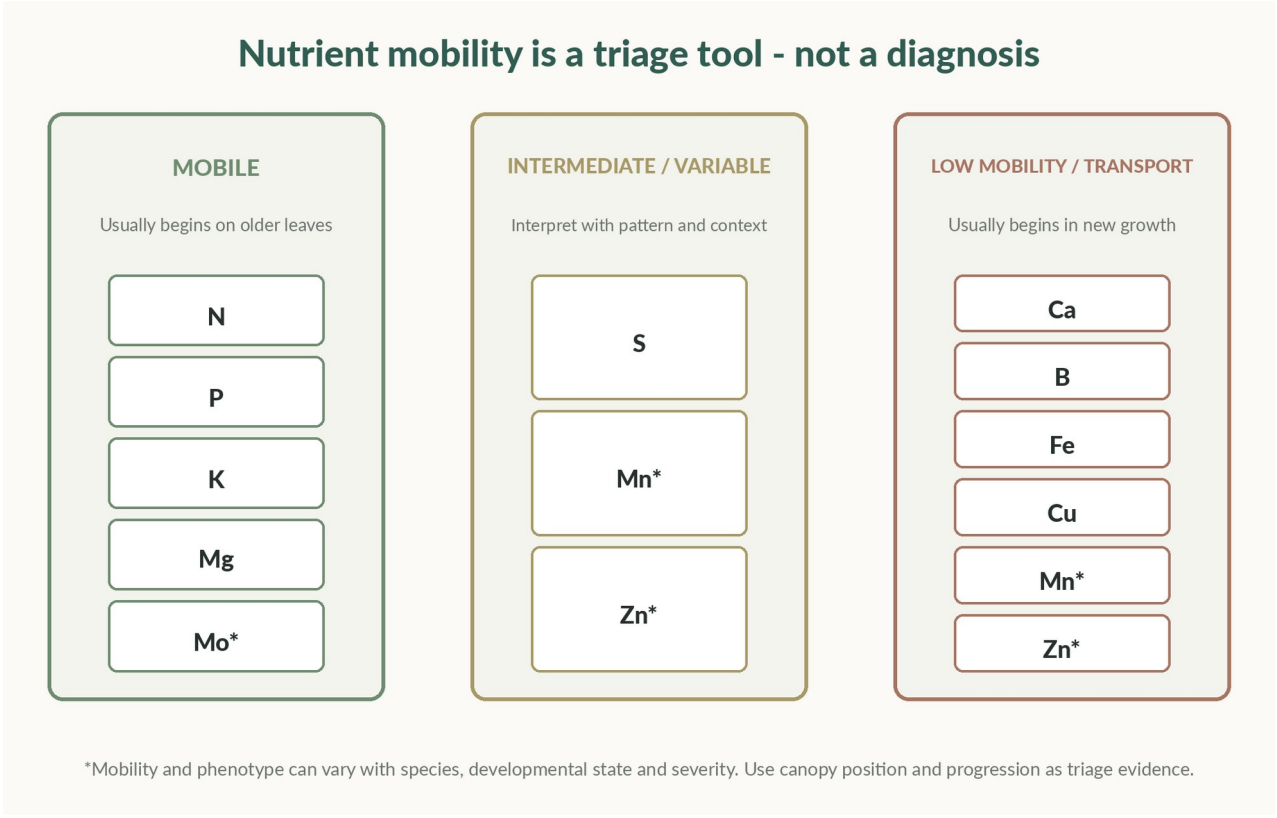


Figure 4. Nutrient mobility is a triage aid, not a diagnosis. Cannabis phenotype and apparent mobility can vary with stage and severity. [1,2,30]

Natural senescence is a serious confounder

In flowering cannabis, adequately supplied control plants can develop chlorosis on the oldest fan leaves late in the cycle. Llewellyn and colleagues observed this from approximately week six of flowering, even when control tissue values were broadly consistent with published ranges. Late lower-leaf yellowing therefore requires a trajectory comparison rather than an automatic deficiency label. [2,3,4]

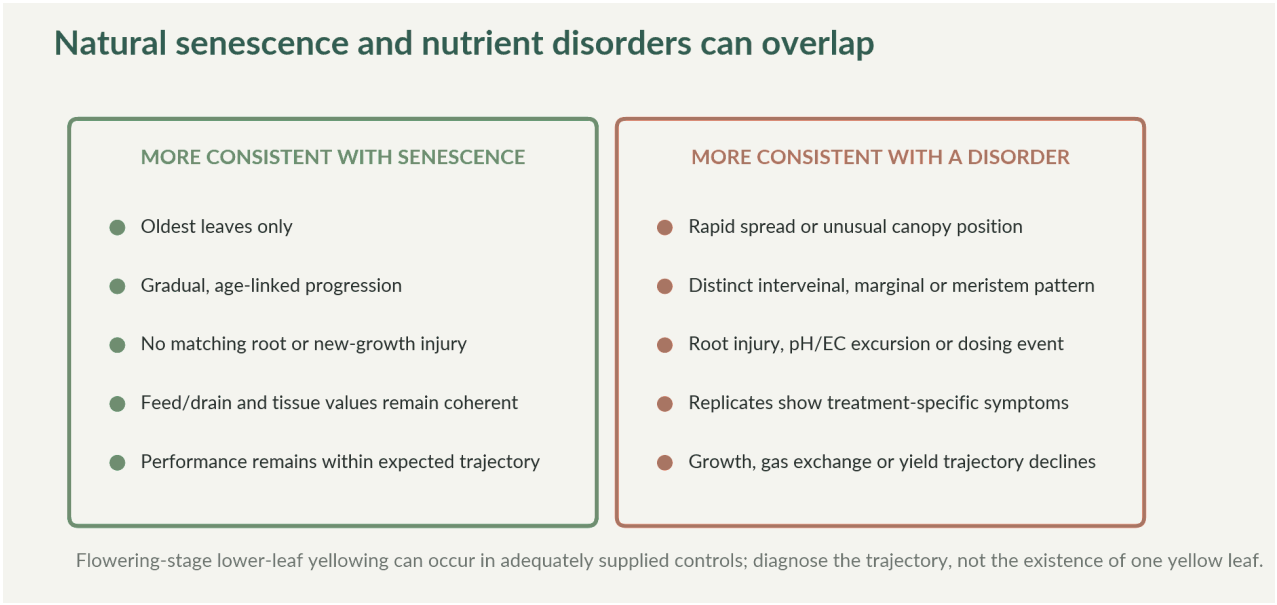


Figure 5. A trajectory-based distinction between natural senescence and a developing disorder. [2,27]

Why a photograph is not enough

The same visible margin injury can arise from low K, B or Mn toxicity, high EC, drought, heat, root disease or a local Ca-transport problem. Likewise, upper chlorosis can reflect Fe, Mn or Zn restriction, pH, roots, light injury or biological stress. Controlled studies repeatedly show that tissue values, visible symptoms and final yield do not always change together. [1,2,12,15,18,27,30]

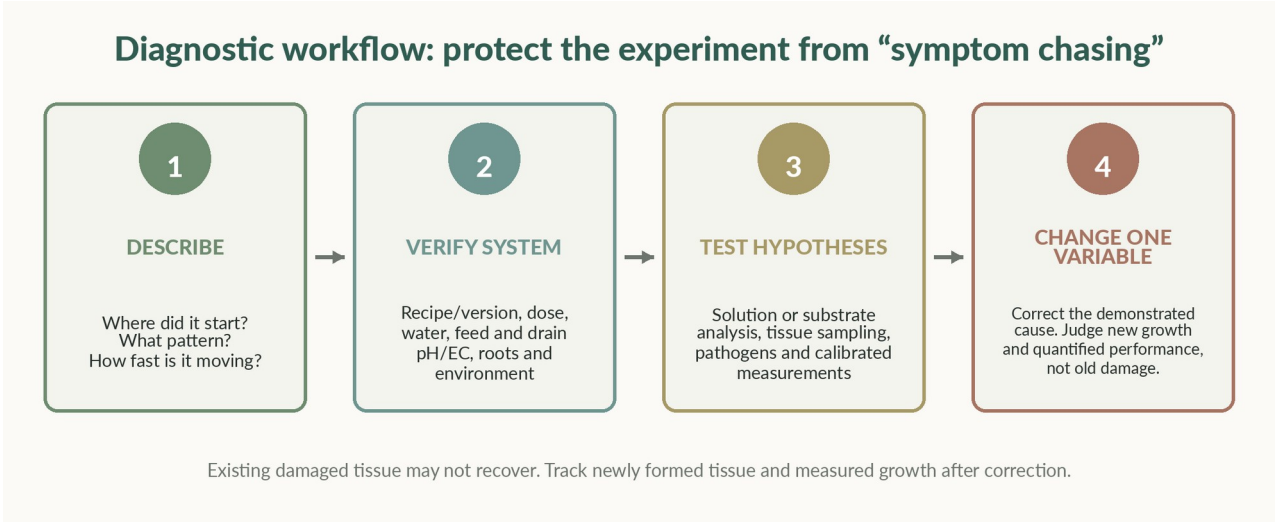


Figure 6. A controlled diagnostic workflow that prevents symptom chasing. [1,2,27,31]

3. Rapid symptom key

Use this to prioritise tests, not to prescribe a correction

Observed pattern	First affected tissue	Leading candidates	Distinguishing clues	Confirm first	Profiles
Uniform pale/yellow lower foliage	Older leaves	N deficiency	Uniform paling starts low and progresses upward; stunting is common.	Feed/drain EC and pH; roots; recipe and dose; MRML tissue N.	D-N-01
Interveinal yellowing on newest leaves	Upper/newest leaves	Fe, Mn or Zn restriction	Fe is often pale between veins; Mn may show fine netting and small tan spots; Zn often affects margins and expansion.	Root-zone pH/alkalinity; roots; trace stock; tissue Fe/Mn/Zn.	D-FE-01 / D-MN-01 / D-ZN-01 / I-PH-01
Yellow/brown lower leaf margins	Older leaves	K deficiency, B/Mn toxicity, high EC	K begins at serrated margins; B/Mn toxicities move inward; rising drain EC favours salt stress.	Feed/drain EC; K/Ca/Mg; tissue B/Mn; irrigation uniformity.	D-K-01 / T-B-01 / T-MN-01 / T-EC-01
Burned or distorted upper margins	Newest tissue	Ca transport/supply, B/Cu/Zn deficiency	Upper-only injury and distorted expansion implicate low-mobility nutrients or transport.	Leaf VPD/airflow; roots; Ca/K/Mg; pH; tissue B/Cu/Zn.	D-CA-01 / D-B-01 / D-CU-01 / D-ZN-01 / I-VPD-01
Interveinal yellowing with green veins on old leaves	Older leaves	Mg deficiency	Green-vein netting precedes tan interveinal spots; margins are not the first feature.	Feed/drain/tissue Mg, K and Ca; pH; roots.	D-MG-01
Dark or lush foliage with weak flowering	Whole canopy	Supra-optimal N or high total strength	Excess vegetative growth without a unique lesion; colour alone is weak evidence.	Elemental N; EC; DLI; tissue N; recipe/stage match.	T-N-01 / T-EC-01 / S-FLOW-NUT
Slow inflorescence initiation or expansion	Reproductive sites	Nutrition, environment or biology	A coherent leaf/root pattern supports nutrition; no pattern plus RH/photoperiod issues favours environment.	Recipe and N form; feed/drain EC/pH; roots; DLI; VPD; temperature; uninterrupted dark period; disease testing.	S-FLOW-NUT / S-FLOW-ENV / T-NH4-01
Rapid burn after feeding or rising drain EC	Margins/roots/whole plant	High EC, dosing or final-volume error	Non-specific injury after an operational event; individual ions can accumulate before visible injury.	Calibrated feed/drain EC; volume; source water; stock and meter records.	T-EC-01
Small twisted new leaves or dead growing tip	Newest tissue	Ca, B, Cu or Zn deficiency; biological/chemical injury	Ca/B can kill meristems; Cu/Zn require trace-level confirmation.	Shoot/root tips; pH; trace stock; tissue analysis; VPD; pests/viroid.	D-CA-01 / D-B-01 / D-CU-01 / D-ZN-01
Performance decline without a clear leaf symptom	No reliable location	Mo deficiency, P/EC accumulation, roots, environment or disease	Some disorders are visually silent; absence of symptoms does not establish adequacy.	Solution/tissue analysis; mass balance; roots; environment; disease testing.	D-MO-01 / T-P-01 / T-EC-01 / S-FLOW-ENV

Stop condition

If the symptom is spreading rapidly, roots are brown or odorous, plants are wilting despite wet substrate, or the pattern follows propagation lines rather than irrigation chemistry, prioritise biological and root-zone testing before nutrient adjustment. [27,28,29]

4. Tissue analysis and reference concentrations

Contextual evidence, not magic thresholds

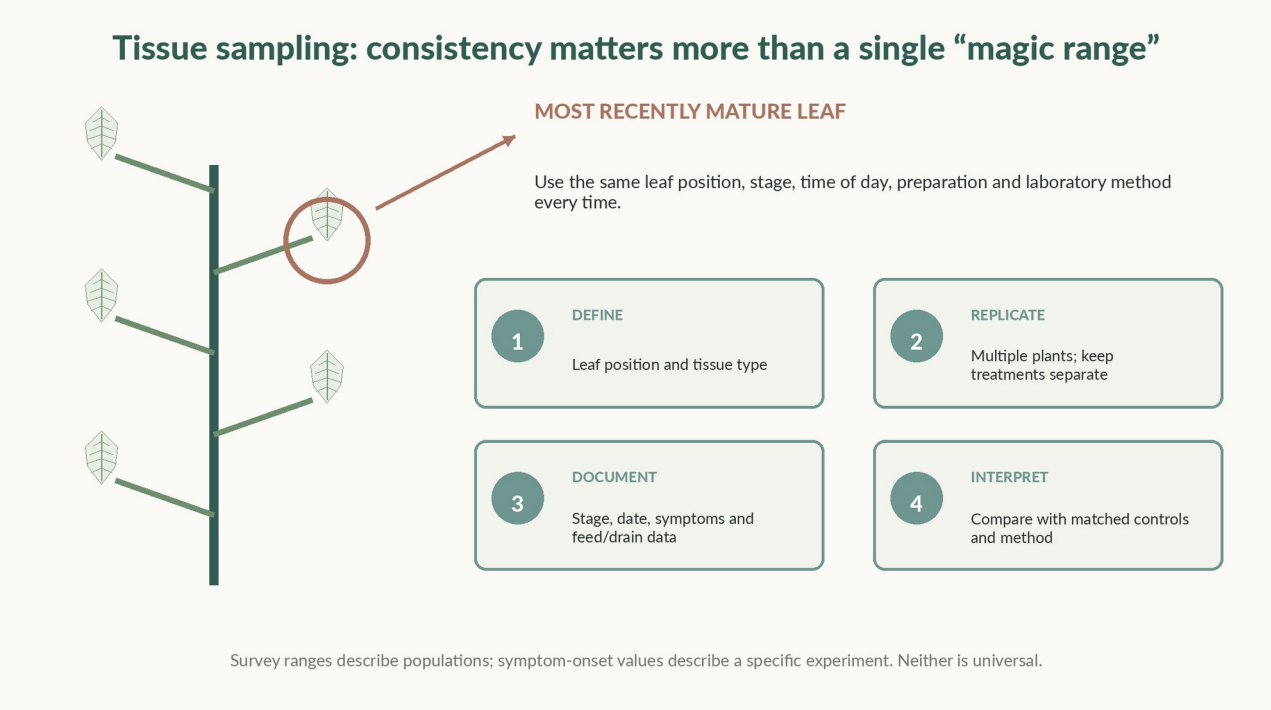


Figure 7. Tissue sampling consistency is more important than a single universal range. [1,2,3,4]

The following values are from a controlled vegetative hemp omission experiment at first visible symptom, with its complete-solution control and published survey ranges. They are useful anchors for method development, but they are not universal cut-offs for every cultivar, stage, leaf position or analytical laboratory. [1,3,4]

Element	MRML at symptom onset	Control MRML	Published survey context	Approx. onset
N	1.62%	4.28%	3.30-4.76%	~6 weeks
P	0.09%	0.43%	0.24-0.49%	~7 weeks
K	0.41%	2.85%	1.83-2.35%	~9 weeks
Ca	0.39%	3.73%	1.47-4.42%	~5 weeks
Mg	0.12%	0.61%	0.40-0.81%	~7 weeks
S	0.11%	0.41%	0.17-0.26%	~7 weeks

Element	MRML in omission treatment	Control MRML	Published survey context
Fe	60.08 mg/kg	111.75 mg/kg	100-150 mg/kg
Mn	7.56 mg/kg	29.4 mg/kg	41-93 mg/kg
Zn	10.7 mg/kg	25.33 mg/kg	24-52 mg/kg
B	2.46 mg/kg	58.58 mg/kg	56-105 mg/kg
Cu	1.41 mg/kg	4.65 mg/kg	5.0-7.1 mg/kg
Mo	0.06 mg/kg	1.46 mg/kg	0.5-1.5 mg/kg

Flowering-stage work reinforces the limitations of single-point tissue analysis. Upper and lower canopy values can differ; symptom onset can occur before or after a concentration crosses a published range; and late-cycle senescence can resemble deficiency despite apparently adequate concentrations. [2,3,4]

Minimum sampling record

- Cultivar or accession, plant age, stage and days from the most recent environmental or nutrient change. [1,2]
- Exact leaf position and tissue type; do not mix old fan leaves, recently mature leaves and sugar leaves in one sample. [1,2,3]
- Feed and drain pH/EC, solution composition, water profile and irrigation volume at the sampling interval. [18,31]
- Root appearance, substrate condition, VPD/RH, PPFD/DLI and temperature. [25,26,27,33]
- Laboratory, digestion/extraction method, dry-mass basis and any washing procedure. [1,2,3,4]

5. Macronutrient deficiencies

Nitrogen, phosphorus and potassium

The macronutrient profiles below combine the original controlled symptom descriptions with later dose-response and flowering-stage evidence. The symptom sequence is useful; the concentration required to prevent it remains cultivar-, stage- and system-dependent. [1,2,5,7,8,16,18,19,20]

D-N-01 Nitrogen deficiency

Class	Factor	First affected tissue	Evidence grade
Deficiency	N	Lower / older leaves	A

Recognise the pattern

Slight stunting; lower foliage becomes pale green or uniformly yellow. Yellowing progresses upward; older leaves become fully yellow, necrotic and may abscise. [1,2,5,20,35]

Why it matters

Reduced canopy and biomass; inadequate N during flowering can reduce inflorescence yield. [1,2,5,20,35]

Evidence synthesis

Two controlled omission experiments place the earliest reliable pattern on older foliage and show major biomass or floral-yield penalties. Dose-response work also shows that both under-supply and excess can restrict performance, so the diagnosis must establish the supplied elemental N and the stage rather than relying on colour alone. [1,2,5,20,35]

Common triggers and close mimics

Common triggers	Key mimics
Low total N, under-dosing, depleted reservoir, excessive leaching, poor roots.	Root disease, chronic overwatering, low light, senescence.

Confirm before changing nutrition

Check feed and drain EC/pH; verify stock/injector; inspect roots; sample most recent mature leaf (MRML). [1,2,5,20,35]

Controlled response

Confirm the mass balance and root-zone conditions before increasing N; correct the cause gradually and recheck new growth. [1,2,5,20,35]

Evidence field	Reported value / context
Study condition / onset	Single-nutrient omission; symptoms at ~6 weeks.
Tissue at symptom onset / condition	MRML 1.62% N at symptom onset.
Reference / control context	Control 4.28%; published survey 3.30–4.76%.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for phenotype; tissue values cultivar/system specific [1,2,5,20,35]

D-P-01 Phosphorus deficiency

Class	Factor	First affected tissue	Evidence grade
Deficiency	P	Lower / older leaves	A

Recognise the pattern

Slight stunting; irregular olive-green or dull areas on older foliage. Spots enlarge, become sunken or wet-looking; marginal and local necrosis develops. [1,2,7,13,16,17,18]

Why it matters

Low P can reduce growth and inflorescence yield; severe stress can confound metabolite concentration with lower biomass. [1,2,7,13,16,17,18]

Evidence synthesis

Controlled omissions show stunting and older-leaf discoloration, but flowering studies disagree on the concentration required for maximum yield because cultivars, root-zone systems and irrigation delivery differ. The common result is that severe shortage is damaging while excess P can accumulate without a proportional production benefit. [1,2,7,13,16,17,18]

Common triggers and close mimics

Common triggers	Key mimics
Insufficient P, high root-zone pH, precipitation with Ca, cold or damaged roots.	K deficiency, foliar disease, waterlogging/root injury.

Confirm before changing nutrition

Measure feed/drain pH and EC; inspect stock compatibility; tissue/solution P analysis; check for haze or sediment. [1,2,7,13,16,17,18]

Controlled response

Do not add a bloom booster from appearance alone; verify soluble P and root-zone pH, then restore the intended balanced profile. [1,2,7,13,16,17,18]

Evidence field	Reported value / context
Study condition / onset	Single-nutrient omission; symptoms at ~7 weeks.
Tissue at symptom onset / condition	MRML 0.09% P at symptom onset.
Reference / control context	Control 0.43%; survey 0.24–0.49%.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for deficiency phenotype; optimum is stage/system dependent [1,2,7,13,16,17,18]

D-K-01 Potassium deficiency

Class	Factor	First affected tissue	Evidence grade
Deficiency	K	Lower / older leaves	A

Recognise the pattern

Yellowing begins along leaflet margins and serrations; interior may remain green initially. Marginal chlorosis advances inward and becomes tan/brown marginal necrosis; growth and function decline. [1,2,6,8,16]

Why it matters

At very low K, plant function and inflorescence yield fall; deficiency stress may misleadingly raise metabolite percentage while total output falls. [1,2,6,8,16]

Evidence synthesis

Older-leaf marginal chlorosis progressing to necrosis is the most consistent visual clue. Direct studies also show strong genotype dependence and cation interactions, so a K-like pattern can arise from high Ca or Mg, substrate release, or salt accumulation rather than a low feed concentration alone. [1,2,6,8,16]

Common triggers and close mimics

Common triggers	Key mimics
Low K, high Ca/Mg competition, excessive leaching, root dysfunction.	High EC/salt burn, drought, Mg deficiency, natural lower-leaf senescence.

Confirm before changing nutrition

Compare margin pattern with feed/drain EC; measure K, Ca and Mg in solution/tissue; inspect irrigation uniformity. [1,2,6,8,16]

Controlled response

Correct water/EC/root causes first; restore the full balanced recipe rather than adding K without accounting for Ca and Mg. [1,2,6,8,16]

Evidence field	Reported value / context
Study condition / onset	Single omission symptoms at ~9 weeks; 15 mg/L K caused chlorosis and lower yield in a flowering dose-response.
Tissue at symptom onset / condition	MRML 0.41% K at symptom onset.
Reference / control context	Control 2.85%; survey 1.83–2.35%.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for phenotype; dose response is genotype dependent [1,2,6,8,16]

6. Secondary-nutrient deficiencies

Calcium, magnesium and sulfur

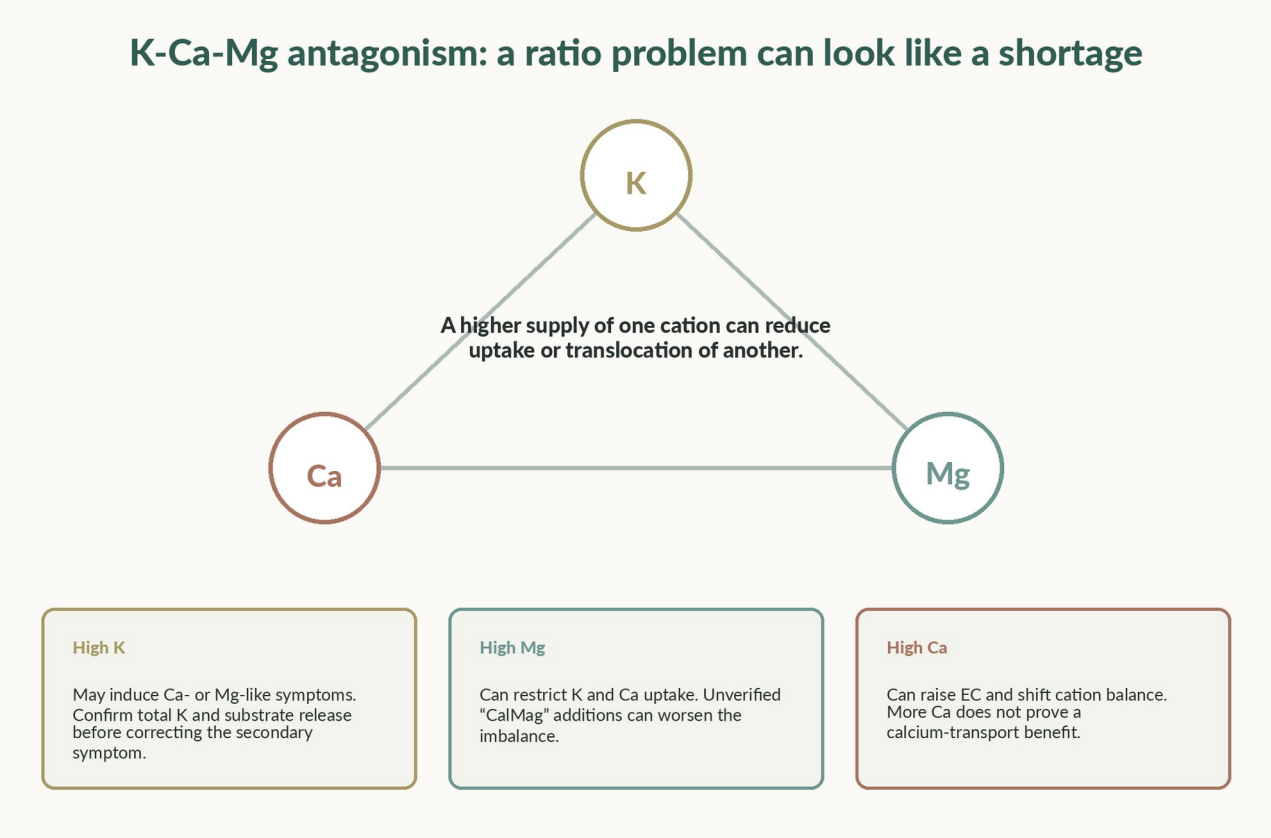


Figure 8. K-Ca-Mg antagonism means a ratio problem can resemble a simple shortage. [6,8,10,11,14,30]

D-CA-01 Calcium deficiency

Class	Factor	First affected tissue	Evidence grade
Deficiency	Ca	Growing tips / newest leaves	A

Recognise the pattern

New leaves are small, narrow or distorted; pale tissue develops near leaflet bases; marginal burn may appear on upper foliage. Interveinal chlorosis and marginal necrosis intensify; meristems may die, causing abnormal axillary proliferation. [1,2,25,30]

Why it matters

Damaged growing points and reduced expansion can restrict canopy and reproductive development even when bulk-solution Ca is adequate. [1,2,25,30]

Evidence synthesis

The direct omission phenotype is concentrated in expanding tissues and meristems. Because calcium delivery depends strongly on xylem flow, an adequate bulk-solution concentration does not rule out a local transport disorder caused by humidity, airflow, irrigation or root damage. [1,2,25,30]

Common triggers and close mimics

Common triggers	Key mimics
Low Ca, high K/Mg, high RH or low VPD, weak airflow, root damage, poor irrigation.	Light/heat injury, B deficiency, pests, broadleaf herbicide injury.

Confirm before changing nutrition

Check whether symptoms are upper-only; measure root-zone Ca/K/Mg, VPD, airflow and root health; tissue analysis. [1,2,25,30]

Controlled response

Distinguish supply deficiency from transport failure. Correct transpiration/root-zone conditions before adding more Ca. [1,2,25,30]

Evidence field	Reported value / context
Study condition / onset	Single-nutrient omission; symptoms at ~5 weeks.
Tissue at symptom onset / condition	MRML 0.39% Ca at symptom onset.
Reference / control context	Control 3.73%; survey 1.47–4.42%.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for phenotype; transport disorders may occur at adequate solution Ca [1,2,25,30]

D-MG-01 Magnesium deficiency

Class	Factor	First affected tissue	Evidence grade
Deficiency	Mg	Lower / older leaves	A

Recognise the pattern

Interveinal chlorosis develops on older leaves while veins remain green, producing a netted pattern. Contrast increases; tan or brown interveinal necrotic spots develop and symptoms move upward. [1,2,10,11,14]

Why it matters

Reduced pigments, photosynthesis and biomass can restrict later inflorescence potential. [1,2,10,11,14]

Evidence synthesis

Older-leaf interveinal chlorosis is consistent across omission and dose-response studies. Both deficiency and over-supply are documented, and high Mg can restrict K and Ca uptake; analytical confirmation should therefore evaluate all three cations together. [1,2,10,11,14]

Common triggers and close mimics

Common triggers	Key mimics
Low Mg, high K or Ca competition, RO water without Mg, root/pH problems.	K deficiency, Mn deficiency, root disease, natural senescence.

Confirm before changing nutrition

Compare interveinal pattern with marginal K injury; measure K:Ca:Mg in feed/drain/tissue. [1,2,10,11,14]

Controlled response

Confirm antagonism versus true under-supply; restore balanced cations and root-zone pH rather than stacking an unaccounted CalMag product. [1,2,10,11,14]

Evidence field	Reported value / context
Study condition / onset	Single omission symptoms at ~7 weeks; 2 mg/L Mg caused deficiency in a vegetative dose-response.
Tissue at symptom onset / condition	MRML 0.12% Mg at symptom onset.
Reference / control context	Control 0.61%; survey 0.40–0.81%.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High [1,2,10,11,14]

D-S-01 Sulfur deficiency

Class	Factor	First affected tissue	Evidence grade
Deficiency	S	Middle to upper / newer leaves	A

Recognise the pattern

General paling, often clearest around the midrib and base of younger or middle leaves. Yellowing becomes more pronounced but may remain less patterned than Fe or Mn deficiency. [1,2,30]

Why it matters

Reduced protein synthesis and growth; likely lower productive capacity if prolonged. [1,2,30]

Evidence synthesis

Sulfur omission produces general paling of relatively young or middle foliage, but the pattern is less distinctive than the N, Mg or Fe phenotypes. Cannabis-specific dose-response evidence remains limited, so formulation and tissue checks carry more weight than visual diagnosis. [1,2,30]

Common triggers and close mimics

Common triggers	Key mimics
Low sulfate, formulation/stock error, excessive precipitation or root dysfunction.	N deficiency, Fe deficiency, high-pH chlorosis.

Confirm before changing nutrition

Verify sulfate-S in formulation and water; compare tissue age pattern; tissue analysis; inspect stocks. [1,2,30]

Controlled response

Confirm the recipe and stock preparation; correct the missing source only after excluding N and pH-related chlorosis. [1,2,30]

Evidence field	Reported value / context
Study condition / onset	Single-nutrient omission; symptoms at ~7 weeks.
Tissue at symptom onset / condition	MRML 0.11% S at symptom onset.
Reference / control context	Control 0.41%; survey 0.17–0.26%.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for phenotype; limited cannabis dose-response data [1,2,30]

7. Micronutrient deficiencies

Iron, manganese, zinc, boron, copper and molybdenum

Micronutrient symptoms are concentrated in young tissues when transport or mobility is low, but pH, chelation, root condition and cultivar strongly affect availability and accumulation. The safe interval can be narrow, especially for B, Cu and Zn. [1,2,12,15,30]

D-FE-01 Iron deficiency

Class	Factor	First affected tissue	Evidence grade
Deficiency / functional lockout	Fe	Upper / newest leaves	A

Recognise the pattern

Newest foliage becomes lighter; yellowing begins near leaflet bases or between veins while lower foliage remains dark green. Upper interveinal chlorosis intensifies and can become nearly uniform if severe. [1,2,15,30]

Why it matters

Reduced chlorophyll and photosynthesis can slow growth and reproductive development. [1,2,15,30]

Evidence synthesis

The strongest clue is upper-canopy chlorosis with older foliage initially greener. Flowering-stage omission work found that visual and tissue signals did not always align, which makes root-zone pH, chelate stability and root health essential parts of confirmation. [1,2,15,30]

Common triggers and close mimics

Common triggers	Key mimics
Low Fe, high root-zone pH/alkalinity, unstable chelate, root disease or poor aeration.	Mn or S deficiency, light bleaching, root hypoxia.

Confirm before changing nutrition

Measure feed/drain pH and alkalinity; verify chelate form and stock; inspect roots; tissue Fe plus Mn. [1,2,15,30]

Controlled response

Treat pH/root cause first. Adding Fe without correcting high pH or root damage may not restore uptake. [1,2,15,30]

Evidence field	Reported value / context
Study condition / onset	Single-nutrient omission; symptoms at ~9 weeks.
Tissue at symptom onset / condition	MRML 60.08 mg/kg Fe at symptom onset.
Reference / control context	Control 111.75 mg/kg; survey 100–150 mg/kg.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for phenotype; tissue Fe interpretation is method sensitive [1,2,15,30]

D-MN-01 Manganese deficiency

Class	Factor	First affected tissue	Evidence grade
Deficiency / functional lockout	Mn	Upper / central leaves	A

Recognise the pattern

Bright yellow, finely netted interveinal chlorosis starts near the midrib and spreads outward. Small tan interveinal necrotic spots may appear while veins remain greener. [1,2,15,30]

Why it matters

Reduced photosynthetic function and growth when prolonged. [1,2,15,30]

Evidence synthesis

A finely netted upper-leaf chlorosis with small tan spots was documented in vegetative omission work, whereas flowering omission produced little yield response. Low-pH oversupply can also create Mn-like injury, so pH and tissue Fe/Mn must be interpreted together. [1,2,15,30]

Common triggers and close mimics

Common triggers	Key mimics
Low Mn, high root-zone pH, excessive alkalinity, root dysfunction.	Fe deficiency, Mg deficiency, light injury.

Confirm before changing nutrition

Measure pH/alkalinity; compare Fe and Mn tissue levels; inspect root health and trace-stock preparation. [1,2,15,30]

Controlled response

Correct pH or trace-delivery error only after distinguishing Mn from Fe and Mg patterns. [1,2,15,30]

Evidence field	Reported value / context
Study condition / onset	Single-nutrient omission; symptoms at ~6 weeks.
Tissue at symptom onset / condition	MRML 7.56 mg/kg Mn at symptom onset.
Reference / control context	Control 29.4 mg/kg; survey 41–93 mg/kg.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for phenotype; survey/control differences require caution [1,2,15,30]

D-ZN-01 Zinc deficiency

Class	Factor	First affected tissue	Evidence grade
Deficiency / functional lockout	Zn	Newest / expanding leaves	A

Recognise the pattern

Marginal yellowing appears on new leaves, often most visible around serrated edges. Tan irregular marginal necrosis develops; new foliage may remain small or poorly expanded. [1,12,15,30]

Why it matters

Restricted shoot expansion and meristem activity can reduce productive architecture. [1,12,15,30]

Evidence synthesis

Young-leaf mottling or interveinal chlorosis, restricted expansion and tip injury are supported by both omission and direct Zn dose-response work. The 2026 dose-response establishes that deficiency and excess can reduce performance, with the optimum specific to the tested cultivar and conditions. [1,12,15,30]

Common triggers and close mimics

Common triggers	Key mimics
Low Zn, high pH, excessive P, trace-mix error, damaged roots.	Ca or B deficiency, light/heat injury, mites.

Confirm before changing nutrition

Check upper-leaf location; measure pH and tissue Zn/P; verify trace-stock mass and uniformity. [1,12,15,30]

Controlled response

Correct root-zone pH or trace-delivery error; avoid adding Zn without confirming because the safe range is narrow. [1,12,15,30]

Evidence field	Reported value / context
Study condition / onset	Single-nutrient omission; symptoms at ~9 weeks.
Tissue at symptom onset / condition	MRML 10.7 mg/kg Zn at symptom onset.
Reference / control context	Control 25.33 mg/kg; survey 24–52 mg/kg.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for deficiency phenotype [1,12,15,30]

D-B-01 Boron deficiency

Class	Factor	First affected tissue	Evidence grade
Deficiency	B	Growing tips / newest leaves and roots	A

Recognise the pattern

New foliage is small, narrow at the leaflet base, distorted or curled inward/down; growing tips lose vigour. Leaf margins become necrotic; shoot and root meristems may die; severe plants wilt. [1,2,15,30]

Why it matters

Meristem failure can stop canopy and inflorescence development. [1,2,15,30]

Evidence synthesis

Boron deficiency and toxicity can both damage margins and growing points. The controlled omission and tenfold-supply treatments demonstrate a narrow diagnostic margin, so correction without water, stock and tissue analysis carries a high risk of overshoot. [1,2,15,30]

Common triggers and close mimics

Common triggers	Key mimics
Low B, trace-mix error, restricted roots, poor transpiration, extreme pH.	Ca deficiency, herbicide injury, mites, root disease.

Confirm before changing nutrition

Inspect both shoot and root tips; verify B in water and trace stock; measure pH; tissue analysis. [1,2,15,30]

Controlled response

Do not diagnose from curl alone. Confirm trace-stock preparation and root condition before any B correction. [1,2,15,30]

Evidence field	Reported value / context
Study condition / onset	Single-nutrient omission; symptoms at ~6 weeks.
Tissue at symptom onset / condition	MRML 2.46 mg/kg B at symptom onset.
Reference / control context	Control 58.58 mg/kg; survey 56–105 mg/kg.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High; B has a narrow deficiency-to-toxicity margin [1,2,15,30]

D-CU-01 Copper deficiency

Class	Factor	First affected tissue	Evidence grade
Deficiency	Cu	Newest leaves / shoot tips	A

Recognise the pattern

Slight stunting; new leaves become distorted with narrow yellow bases, marginal/interveinal chlorosis and inward/down curl. Reduced turgor and more severe distortion develop; shoot growth is restricted. [1,2,15,30]

Why it matters

Substantial biomass loss was recorded in the omission study; productive growth is likely constrained. [1,2,15,30]

Evidence synthesis

Copper omission caused distorted new growth and substantial biomass loss in the vegetative phenotype study. Because the required concentration is small and excess can also be damaging, this should be treated as an analytical diagnosis rather than corrected from appearance alone. [1,2,15,30]

Common triggers and close mimics

Common triggers	Key mimics
Low Cu, high pH, trace-mix error, over-chelation or root injury.	B/Ca deficiency, heat/light injury, pests.

Confirm before changing nutrition

Verify trace-stock mass and mixing; pH; tissue Cu; inspect roots and shoot tips. [1,2,15,30]

Controlled response

Because Cu is required at low concentration and can become toxic, confirm analytically before changing it. [1,2,15,30]

Evidence field	Reported value / context
Study condition / onset	Single-nutrient omission; symptoms at ~9 weeks.
Tissue at symptom onset / condition	MRML 1.41 mg/kg Cu at symptom onset.
Reference / control context	Control 4.65 mg/kg; survey 5.0–7.1 mg/kg.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for phenotype; narrow operational range [1,2,15,30]

D-MO-01 Molybdenum deficiency

Class	Factor	First affected tissue	Evidence grade
Latent deficiency	Mo	No reliable visual location in the cited cannabis study	A

Recognise the pattern

No visible symptoms developed during the nine-week omission experiment. A biochemical deficiency may exist without a useful visual signature. [1,2,3,30]

Why it matters

Unknown from appearance alone; nitrate metabolism may be affected before a distinctive phenotype appears. [1,2,3,30]

Evidence synthesis

The cannabis omission study produced a strong tissue depletion but no useful visual symptom within nine weeks. This is an important negative result: normal-looking foliage cannot demonstrate adequate molybdenum supply. [1,2,3,30]

Common triggers and close mimics

Common triggers	Key mimics
Trace-mix omission, very low pH, analytical or formulation error.	General N stress or no visible disorder.

Confirm before changing nutrition

Do not rely on appearance; verify recipe, trace stock and tissue Mo if suspected. [1,2,3,30]

Controlled response

Treat as an analytical diagnosis, not a visual one. [1,2,3,30]

Evidence field	Reported value / context
Study condition / onset	Single-nutrient omission; no visible symptoms by 9 weeks.
Tissue at symptom onset / condition	MRML 0.06 mg/kg Mo.
Reference / control context	Control 1.46 mg/kg; survey 0.5–1.5 mg/kg.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High evidence that visual screening can miss it [1,2,3,30]

8. Toxicities, over-supply and antagonisms

When more nutrient creates less useful plant function

Over-supply is often visually non-specific. It can appear as dark foliage, marginal burn, root-zone EC rise, delayed stage transition or a secondary deficiency produced by antagonism. Several direct cannabis studies show that tissue accumulation can increase without improving biomass, yield or cannabinoid output. [5,8,9,10,11,12,17,18,35]

T-N-01 Supra-optimal nitrogen

Class	Factor	First affected tissue	Evidence grade
Toxicity / over-supply	N	Whole plant; often dark foliage or lower margin injury	A

Recognise the pattern

Unusually dark or lush foliage, excessive vegetative growth, reduced nutrient-use efficiency; lower-leaf margin injury can occur. Growth restriction, ion imbalance and poor stage transition may develop without a unique diagnostic lesion. [5,20,35,37]

Why it matters

Excessive leaf growth can occur at the expense of flower development; high N can reduce secondary-metabolite concentration. [5,20,35,37]

Evidence synthesis

Supra-optimal N does not have a single pathognomonic lesion. Direct studies report excessive vegetative growth, reduced nutrient-use efficiency, altered partitioning and lower cannabinoid concentration at higher supply, but the inflection point varies with stage, cultivar and system. [5,20,35,37]

Common triggers and close mimics

Common triggers	Key mimics
Over-strength feed, injector error, high-N water/additives, failure to reduce N for stage, low light relative to N.	High EC, K burn, low VPD, genetic dark foliage.

Confirm before changing nutrition

Check actual total N, dose, EC, DLI, tissue N and stock calibration; compare growth partitioning, not colour alone. [5,20,35,37]

Controlled response

Return to the validated recipe/dose after confirming excess; do not infer N toxicity solely from dark green leaves. [5,20,35,37]

Evidence field	Reported value / context
Study condition / onset	30–320 mg/L vegetative dose-response: 160 mg/L optimal; >160 caused restrictions in the tested cultivar.
Tissue at symptom onset / condition	No universal tissue toxicity threshold established.
Reference / control context	Response is stage, cultivar and system dependent.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. Moderate to high for over-supply effect; visual specificity is low [5,20,35,37]

T-NH4-01 High ammonium fraction

Class	Factor	First affected tissue	Evidence grade
Toxicity / nitrogen-form imbalance	NH4-N	Whole plant; roots and older foliage may decline first	A

Recognise the pattern

Reduced vigour may appear before a distinctive leaf pattern; high NH4 can acidify the root zone. At high fractions, physiological injury, severe chlorosis/necrosis, yield loss and plant death can occur. [9]

Why it matters

Inflorescence size and yield declined even at 10–30% NH4-N relative to nitrate-only; ≥50% caused marked toxicity. [9]

Evidence synthesis

In a direct nitrogen-form experiment, nitrate-only nutrition produced the strongest combined yield and secondary-metabolite response. Ten to thirty percent ammonium reduced yield without obvious toxicity; fifty percent produced late injury and one hundred percent caused severe damage or death in the tested cultivar. [9]

Common triggers and close mimics

Common triggers	Key mimics
Wrong calcium nitrate grade, ammonium-containing fertiliser, dosing error, low root-zone pH.	General N excess, root hypoxia, low pH toxicity, high EC.

Confirm before changing nutrition

Calculate NH4-N percentage of total N; measure root-zone pH trend; check fertiliser analyses and roots. [9]

Controlled response

Remove the unintended ammonium source and re-establish the validated nitrate-dominant formulation; avoid abrupt multiple changes. [9]

Evidence field	Reported value / context
Study condition / onset	0, 10, 30, 50 and 100% NH4-N at 200 mg/L total N; 50% toxic late, 100% severe/death.
Tissue at symptom onset / condition	Treatment-based; no single tissue threshold.
Reference / control context	Nitrate-only gave the strongest yield/secondary-metabolite outcome in the study.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High within the tested cultivar and conditions [9]

T-K-01 Potassium over-supply / cation antagonism

Class	Factor	First affected tissue	Evidence grade
Toxicity / imbalance	K	Older foliage may show moderate chlorosis; secondary Ca/Mg symptoms can occur elsewhere	A

Recognise the pattern

Moderate chlorosis may appear at high supply, sometimes without yield change. Physiological impairment is genotype dependent; induced Ca/Mg restriction may resemble those deficiencies. [6,8,16]

Why it matters

No yield benefit was found from raising K above 60 mg/L in the cited reproductive study; metabolites generally declined as K rose. [6,8,16]

Evidence synthesis

K over-supply is mainly a balance problem. Direct studies document genotype-dependent injury and reduced Ca/Mg accumulation as K rises, while reproductive yield did not consistently improve above the lower adequate treatments. [6,8,16]

Common triggers and close mimics

Common triggers	Key mimics
Excess K fertiliser, K2CO3 water treatment, coir K release, inaccurate target correction.	True Ca/Mg shortage, high EC, drought, low-VPD Ca transport failure.

Confirm before changing nutrition

Measure K, Ca and Mg in feed/drain/tissue; include water and substrate K; inspect EC accumulation. [6,8,16]

Controlled response

Correct the total K mass balance and cation ratio, not just the visible secondary symptom. [6,8,16]

Evidence field	Reported value / context
Study condition / onset	15–240 mg/L K flowering study; 240 mg/L impaired one cultivar; 60–175 mg/L supported high function/yield.
Tissue at symptom onset / condition	No universal tissue toxicity threshold.
Reference / control context	Genotype-dependent oversupply response.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for direct supply response; toxicity threshold not universal [6,8,16]

T-MG-01 Magnesium over-supply / cation antagonism

Class	Factor	First affected tissue	Evidence grade
Toxicity / imbalance	Mg	Old lower leaves first in the cited study	A

Recognise the pattern

Subtle lower-leaf toxicity symptoms and reduced pigment/gas-exchange performance may appear. High Mg restricts K and Ca uptake/translocation; secondary deficiency patterns may dominate. [10,11,14]

Why it matters

Physiological function can decline even when biomass initially appears unaffected. [10,11,14]

Evidence synthesis

Direct vegetative and reproductive studies show a transition from deficiency to adequacy and then to excess. High Mg can reduce K and Ca uptake or translocation, allowing a secondary deficiency phenotype to dominate the visual picture. [10,11,14]

Common triggers and close mimics

Common triggers	Key mimics
Excess Mg supplements, Mg-rich water, double dosing, compensating for coir without analysis.	K or Ca deficiency, normal lower-leaf ageing, high EC.

Confirm before changing nutrition

Measure Mg, Ca and K in solution/tissue; audit all CalMag and water inputs; compare feed/drain. [10,11,14]

Controlled response

Reduce the unaccounted Mg source and restore the intended cation balance after confirmation. [10,11,14]

Evidence field	Reported value / context
Study condition / onset	2–140 mg/L Mg vegetative study; 35–70 optimal; 140 mg/L caused old-leaf toxicity and slight functional inhibition.
Tissue at symptom onset / condition	No universal tissue threshold.
Reference / control context	Direct supply-response evidence.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for the tested vegetative system [10,11,14]

T-P-01 Phosphorus over-supply / luxury accumulation

Class	Factor	First affected tissue	Evidence grade
Over-supply; may be visually silent	P	Often no reliable early visual symptom	A

Recognise the pattern

Plants may look normal while solution and tissue P accumulate. High root-zone nutrient concentration can accumulate without yield or quality improvement; antagonism or precipitation may emerge later. [7,13,17,18]

Why it matters

Higher P did not improve yield or cannabinoid production in the cited closed-system study. [7,13,17,18]

Evidence synthesis

Multiple independent cannabis studies show that P can accumulate in tissue, flowers or leachate without increasing yield or cannabinoid concentration. Absence of visible injury therefore cannot be used as evidence that the P rate is efficient or harmless. [7,13,17,18]

Common triggers and close mimics

Common triggers	Key mimics
Bloom boosters, repeated top-ups, incorrect P2O5-to-P conversion, low drainage, recirculating accumulation.	General high EC, Ca precipitation, micronutrient lockout.

Confirm before changing nutrition

Measure actual elemental P, feed/drain EC and solution ions; check unit conversion and stock compatibility. [7,13,17,18]

Controlled response

Do not use absence of symptoms as proof of safety. Correct the elemental P mass balance and accumulated reservoir chemistry. [7,13,17,18]

Evidence field	Reported value / context
Study condition / onset	15–90 mg/L P at refill EC ~2 or 4 mS/cm; no yield/quality benefit above low treatment.
Tissue at symptom onset / condition	No visual toxicity threshold established.
Reference / control context	Higher EC/P increased accumulation without visible injury in that experiment.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for lack of benefit and accumulation; low for a visual toxicity signature [7,13,17,18]

T-B-01 Boron toxicity

Class	Factor	First affected tissue	Evidence grade
Toxicity	B	Lower / older leaves	A

Recognise the pattern

Yellowing begins at lower leaf margins and moves inward. Brown or necrotic margins expand; leaves may become severely damaged. [1,15]

Why it matters

Loss of functional leaf area and reduced growth; B has a narrow operational margin. [1,15]

Evidence synthesis

The tenfold B treatment generated older-leaf marginal chlorosis and necrosis with very high tissue B. Because similar margins occur with K shortage, salt stress and drought, water and trace-stock audits are required before attribution. [1,15]

Common triggers and close mimics

Common triggers	Key mimics
Trace-stock weighing error, B-rich water, duplicate micronutrient products, evaporation/EC accumulation.	K deficiency, general salt burn, drought.

Confirm before changing nutrition

Audit B from water and every product; measure tissue B and feed/drain EC; confirm symptom location. [1,15]

Controlled response

Stop duplicate/unintended B inputs and replace contaminated solution only after confirming the source. [1,15]

Evidence field	Reported value / context
Study condition / onset	Tenfold B treatment; symptoms at ~7 weeks.
Tissue at symptom onset / condition	MRML 671.75 mg/kg B in toxicity treatment.
Reference / control context	Control 64.6 mg/kg; survey 56–105 mg/kg.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for phenotype under the experimental treatment [1,15]

T-MN-01 Manganese toxicity

Class	Factor	First affected tissue	Evidence grade
Toxicity	Mn	Lower / older leaves in the cited study	A

Recognise the pattern

Lower margins turn yellow and chlorosis advances inward. Severe chlorosis, marginal necrosis and leaf abscission may develop. [1,15]

Why it matters

Loss of lower canopy; threshold remains uncertain because tissue concentrations overlapped survey values. [1,15]

Evidence synthesis

The tenfold Mn treatment generated lower-leaf chlorosis and necrosis, but tissue values overlapped ranges reported in other cannabis surveys. The original authors therefore cautioned against treating the observed concentration as a universal toxicity threshold. [1,15]

Common triggers and close mimics

Common triggers	Key mimics
Low root-zone pH, trace-stock overdose, Mn-rich water, injector error.	B toxicity, K deficiency, general salinity.

Confirm before changing nutrition

Measure root-zone pH, water Mn, tissue Mn/Fe and trace-stock concentration. [1,15]

Controlled response

Correct low pH or dosing error; do not declare Mn toxicity from the visual pattern alone. [1,15]

Evidence field	Reported value / context
Study condition / onset	Tenfold Mn treatment; symptoms at ~7 weeks.
Tissue at symptom onset / condition	MRML 47.88 mg/kg Mn in toxicity treatment.
Reference / control context	Control 31.13 mg/kg; published survey 41–93 mg/kg.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. Moderate; authors explicitly cautioned that the threshold needs refinement [1,15]

T-EC-01 High EC / salinity / nutrient accumulation

Class	Factor	First affected tissue	Evidence grade
System toxicity / osmotic stress	Total ions	Margins may burn first; whole plant can be affected	A

Recognise the pattern

Water uptake slows; leaves may darken, curl or develop rapid marginal burn, especially with drought or low drainage. Tip/margin necrosis, reduced growth and root injury; individual ions may accumulate silently before visual injury. [18,31,34]

Why it matters

Higher nutrient concentration can increase tissue/solution accumulation without improving yield or cannabinoid output. [18,31,34]

Evidence synthesis

High EC is an osmotic and compositional problem rather than a nutrient diagnosis. Controlled closed-system studies show that increasing nutrient concentration can increase solution and tissue accumulation without a yield or quality benefit and without requiring a unique visible toxicity signature. [18,31,34]

Common triggers and close mimics

Common triggers	Key mimics
Over-concentrated stocks, evaporation, low drainage, recirculating top-ups, poor meter calibration, saline water.	K deficiency, drought, heat/light stress, root disease.

Confirm before changing nutrition

Measure calibrated feed and drain EC, reservoir volume, water EC, individual ions and roots; check dosing and final-volume preparation. [18,31,34]

Controlled response

Correct concentration/volume and irrigation uniformity first; do not diagnose a specific nutrient from salt-burn appearance. [18,31,34]

Evidence field	Reported value / context
Study condition / onset	Closed-system EC ~4 vs ~2 mS/cm increased accumulation without yield/quality benefit; visual injury was not required.
Tissue at symptom onset / condition	No single tissue threshold.
Reference / control context	EC describes ionic concentration, not composition.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. High for accumulation risk; visual specificity is low [18,31,34]

9. Root-zone, environmental and biological mimics

A nutrient-like symptom can originate outside the nutrient formula

I-PH-01 High-pH Fe/Mn lockout

Class	Factor	First affected tissue	Evidence grade
Functional deficiency	Fe / Mn / Zn	Upper / newest leaves	B

Recognise the pattern

Upper interveinal chlorosis appears even when the fertiliser contains adequate trace elements. Chlorosis intensifies; necrotic spotting may develop if Mn or Zn restriction becomes severe. [15,30,31]

Why it matters

Reduced photosynthesis and growth; can be mistaken for an under-strength recipe. [15,30,31]

Evidence synthesis

Substrate-pH experiments show reduced growth at very acidic conditions and strong pH effects on micronutrient accumulation. These results support pH as a differential for Fe, Mn and Zn symptoms, but a substrate-pH result must not be converted into a universal hydroponic solution threshold. [15,30,31]

Common triggers and close mimics

Common triggers	Key mimics
High alkalinity, nitrate-only pH drift, insufficient acid control, unstable chelates, poor roots.	True Fe/Mn/Zn deficiency, light bleaching, root hypoxia.

Confirm before changing nutrition

Measure feed/drain pH and alkalinity over time; tissue Fe/Mn/Zn; inspect roots and chelate form. [15,30,31]

Controlled response

Correct the pH/alkalinity or root cause before increasing trace concentrations. [15,30,31]

Evidence field	Reported value / context
Study condition / onset	Functional differential based on symptomology and nutrient availability; not a standalone cannabis dose-response.
Tissue at symptom onset / condition	Use tissue plus pH, not appearance alone.
Reference / control context	Upper-leaf location is more diagnostic than colour alone.

Evidence grade B

Contextual cannabis evidence: survey, modelling or multi-study synthesis; useful for ranges and interpretation. Moderate; strong physiological basis and practical evidence [15,30,31]

I-VPD-01 Low-transpiration functional Ca disorder

Class	Factor	First affected tissue	Evidence grade
Transport limitation / mimic	Ca transport	Growing tips / newest leaves	C

Recognise the pattern

Upper marginal burn, distorted new growth or localised Ca-like injury occurs despite adequate solution Ca. Meristem and rapidly expanding tissue damage can continue if high RH/low VPD or weak airflow persists. [25,30]

Why it matters

Can restrict new leaf and floral tissue expansion without a low bulk-solution Ca result. [25,30]

Evidence synthesis

Calcium transport to rapidly expanding tissues is xylem dependent. An extreme-humidity cannabis experiment directly demonstrated delayed flowering, low biomass and tip injury under very low VPD, but it was not a dedicated calcium dose-response and does not define an optimum RH range. [25,30]

Common triggers and close mimics

Common triggers	Key mimics
High RH, low VPD, weak airflow, cool leaf temperature, saturated root zone, poor roots.	True Ca or B deficiency, light/heat damage, pests.

Confirm before changing nutrition

Measure leaf VPD, airflow and root-zone moisture; verify solution/tissue Ca and cation balance. [25,30]

Controlled response

Correct transport conditions and root health before increasing Ca; excess Ca can create other antagonisms. [25,30]

Evidence field	Reported value / context
Study condition / onset	Operational differential; Ca omission phenotype provides the visual comparator.
Tissue at symptom onset / condition	No universal tissue threshold for functional transport failure.
Reference / control context	Adequate feed Ca does not exclude local tissue deficiency.

Evidence grade C

Mechanistic support: established plant physiology or substrate mechanism; no cannabis-specific threshold claimed. Moderate; practical evidence plus general Ca physiology [25,30]

Root disease, crown disease and inflorescence disease

Root rots caused by organisms including Pythium and Fusarium can reduce water and nutrient acquisition, produce stunting or chlorosis, and create wet-root symptoms that are easily mistaken for under-fertilisation. Powdery mildew, Botrytis and other foliar or inflorescence pathogens can also reduce growth or quality while leaving the nutrient solution apparently correct. [27,29]

A nutrient correction will not resolve a biological cause. Inspect roots and crowns, map the pattern through propagation and irrigation zones, and use an appropriate diagnostic laboratory when disease is plausible. [27,29]

Hop latent viroid and other systemic biological causes

Hop latent viroid can produce reduced vigour, smaller or distorted young leaves, weak rooting, stunting and reduced inflorescence development. Many infected plants can be subtle or asymptomatic, so the absence of a classic visual signature does not rule it out. [27,28]

Biological differential

When symptoms cluster by clone source, mother plant or propagation batch rather than by nutrient delivery, quarantine the hypothesis and test biological material before reformulating the feed. [27,28,29]

10. Slow or weak inflorescence development

Separate nutrition, environment and biology

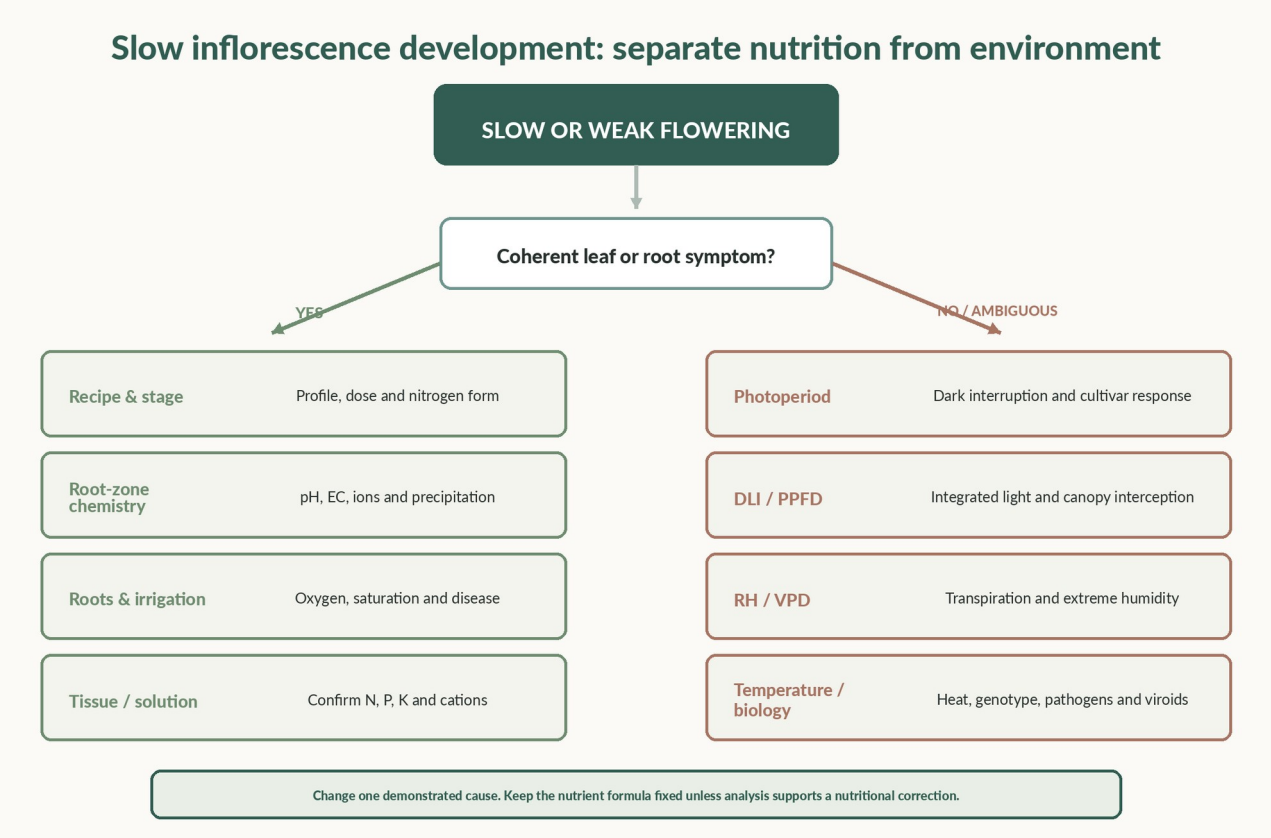


Figure 9. Decision tree for slow or weak flowering. Nutritional correction is only one branch. [9,16,18,22,23,24,25,26,27,28]

S-FLOW-NUT Slow inflorescence development — nutritional differential

Class	Factor	First affected tissue	Evidence grade
Production symptom / differential	N, P, K, NH4, EC	Whole plant and reproductive sites	B

Recognise the pattern

Delayed or weak floral expansion may accompany low vigour, excessive vegetative growth or ion imbalance; there is no single leaf signature. Small inflorescences, poor dry-flower accumulation or persistent leafy growth; symptoms depend on the causal nutrient. [9,16,18,20,35]

Why it matters

Low N/P/K can restrict yield; excess N can favour foliage; NH4 fractions reduce inflorescence size/yield; high EC can accumulate without benefit. [9,16,18,20,35]

Evidence synthesis

Slow flowering has no unique nutritional lesion. Studies show that insufficient N, P or K can restrict yield, high ammonium can reduce inflorescence size, and high root-zone concentration can accumulate nutrients without benefit. The response should be to identify the demonstrated constraint, not to add a generic bloom booster. [9,16,18,20,35]

Common triggers and close mimics

Common triggers	Key mimics
Wrong stage recipe, under/over-strength feed, high NH4, cation antagonism, root-zone accumulation.	Photoperiod errors, high RH/low VPD, low DLI, temperature stress, genotype, pests/root disease.

Confirm before changing nutrition

Compare actual recipe/dose with feed/drain EC and pH; inspect roots; verify N form and tissue N/P/K; audit environmental data. [9,16,18,20,35]

Controlled response

Do not chase flowering with a single nutrient. Identify whether the system is deficient, excessive or environmentally constrained, then change one controlled variable. [9,16,18,20,35]

Evidence field	Reported value / context
Study condition / onset	Multiple dose-response studies; no universal visual threshold for slow flowering.
Tissue at symptom onset / condition	Use biomass rate, inflorescence size and tissue/solution data.
Reference / control context	Yield and concentration endpoints can move in opposite directions.

Evidence grade B

Contextual cannabis evidence: survey, modelling or multi-study synthesis; useful for ranges and interpretation. Moderate to high for component effects; low specificity as a standalone symptom [9,16,18,20,35]

S-FLOW-ENV Slow inflorescence development — environmental differential

Class	Factor	First affected tissue	Evidence grade
Environmental mimic	VPD / RH / photoperiod / DLI	Whole canopy and reproductive sites	A

Recognise the pattern

Plants may remain vegetative-looking or form flowers slowly without a coherent nutrient-deficiency pattern. Delayed floral initiation/development and reduced flower biomass; high humidity can reduce transpiration and confound Ca symptoms. [22,23,24,25,26,27,28,32,33]

Why it matters

One recent controlled study reported a three-week flowering delay and 71% lower flower biomass under elevated RH. [22,23,24,25,26,27,28,32,33]

Evidence synthesis

Photoperiod response is cultivar dependent, and DLI, humidity, temperature, disease and viroids can alter or delay inflorescence development. Recent direct experiments provide strong evidence for these environmental effects, but none supports diagnosing slow flowering from one environmental reading in isolation. [22,23,24,25,26,27,28,32,33]

Common triggers and close mimics

Common triggers	Key mimics
High RH/low VPD, interrupted dark period, wrong photoperiod, low DLI, unsuitable temperature, genotype.	Nutrient deficiency/excess, root disease, pests.

Confirm before changing nutrition

Verify uninterrupted photoperiod, DLI, leaf VPD, temperature, CO2, root health and time from induction before changing nutrition. [22,23,24,25,26,27,28,32,33]

Controlled response

Correct the environmental cause first; maintain the recipe as a controlled variable unless analytical data also show a nutrient problem. [22,23,24,25,26,27,28,32,33]

Evidence field	Reported value / context
Study condition / onset	Controlled high-RH study; effect size is genotype and environment specific.
Tissue at symptom onset / condition	No nutrient tissue threshold.
Reference / control context	Environmental delay can coexist with nutritional stress.

Evidence grade A

Direct cannabis evidence: controlled omission, dose-response, factorial or environmental treatment. Moderate; recent controlled evidence, not yet universal [22,23,24,25,26,27,28,32,33]

Photoperiod and DLI are cultivar-specific variables

A 12-hour flowering photoperiod is reliable but not universally yield-maximising. Ten-cultivar work showed that many cultivars initiated flowering under 13-14 hour days with variable delay, while a later two-cultivar study found 35-50% higher inflorescence dry weight under 13 hours at the tested PPFD. These are cultivar-specific results, not permission to generalise one photoperiod to every genotype. [22,23]

Vegetative DLI can affect the biomass platform available for later flowering. In a night-break experiment, the lower vegetative DLI treatment used less electricity but produced approximately 22% less flower biomass under the tested conditions. [24]

Humidity and temperature can dominate a nutrient-looking problem

An extreme high-RH treatment in one CBD-dominant cultivar delayed visible flowering by three weeks and reduced flower biomass by 71%. The study explicitly cautioned that its lower-RH control was not proof of an optimum range. A separate temperature experiment found that 31/27°C day/night conditions reduced specialised-metabolite yield and altered inflorescence development relative to 25/21°C, with genotype-specific biomass responses. [25,26]

11. Sampling and confirmation protocol

A reproducible sequence for controlled environments

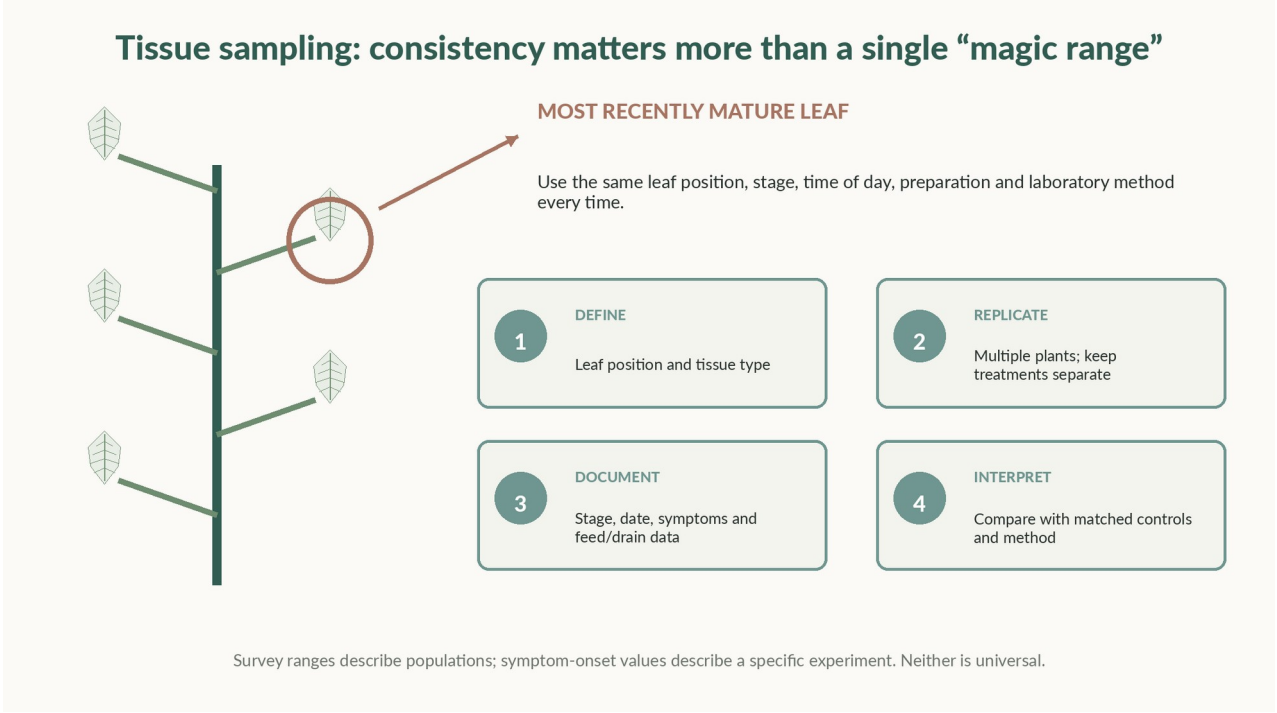


Figure 10. A repeatable leaf-sampling protocol reduces analytical noise. [1,2,3,4]

1	**Freeze the observation -** Record date, plant ID, cultivar, stage, symptom location, progression, environment and photographs before any correction. [1,2,27]
2	**Verify the delivery system -** Confirm recipe ID/version, stock masses, injection or dosing, final volume, water profile, feed pH/EC and meter calibration. [18,31]
3	**Measure the root zone -** Collect feed and drain or reservoir data at matched volume and temperature; inspect roots, substrate saturation and oxygen conditions. [18,27,31]
4	**Test competing hypotheses -** Select tissue position deliberately, submit solution/water/tissue samples where needed, and consider pests, pathogens or viroid. [1,2,27,28,29]
5	**Change one variable -** Correct only a demonstrated cause; retain an untreated or standard control where possible. [1,2,30]
6	**Judge new growth -** Existing chlorosis or necrosis may not reverse. Evaluate newly formed tissue, growth rate, solution balance and quantified yield trajectory. [1,2]

Recommended analytical package

Sample/record	Minimum useful content
Water	EC, pH, alkalinity, NO3-N, NH4-N, P, K, Ca, Mg, S, Na, Cl, Fe, Mn, Zn, B and source/date.
Feed solution	Elemental formulation, pH, EC, major ions and trace package; check actual final volume.
Drain/reservoir	Matched-volume pH and EC, major ions where recirculating or accumulation is suspected.
Tissue	Defined leaf position and tissue type; N, P, K, Ca, Mg, S, Fe, Mn, Zn, B, Cu and Mo.
Biological	Root/crown culture or molecular test, viroid PCR/RT-qPCR, and pest/pathogen inspection when pattern supports it.
Environment	Canopy and leaf temperature, RH/VPD, PPFD, DLI, CO2, root-zone temperature and irrigation timing.

12. Evidence gaps and research priorities

What the literature still cannot support

Gap	Current conclusion	Evidence
Calcium dose response	No dedicated modern controlled cannabis Ca dose-response was identified that establishes a universal solution optimum or toxicity threshold. Existing Ca values are usually background concentrations or formulation consequences.	[1,2,16,30]
Sulfur dose response	The omission phenotype is documented, but stage-specific adequacy and toxicity ranges remain poorly resolved.	[1,2]
Micronutrient interactions	Zn now has a direct dose response, while B, Cu, Mo, Fe and Mn still lack broad multi-cultivar stage-specific curves.	[1,12,15]
Transfer across systems	Perlite, peat-based substrate, coir, DWC, recirculating and drain-to-waste systems alter delivery, storage, pH and ion accumulation.	[2,15,16,18,31]
Cultivar variation	Direct K, photoperiod, temperature, pH and nutrient studies repeatedly show genotype-specific response.	[6,8,15,22,23,26]
Visual thresholds	Many over-supply conditions have weak or non-specific visual signatures, and tissue thresholds overlap across studies.	[1,2,15,18]
Disease-nutrition interactions	Root pathogens and viroid can alter nutrient acquisition and growth, but combined controlled experiments are limited.	[27,28,29]

Research priority

Future work should combine replicated nutrient dose responses with matched solution, root-zone and tissue ionomics, standardised symptom photography, multiple cultivars, yield and total metabolite output, and explicit system chemistry. [1,2,6,8,12,16,18,19]

13. Field worksheets

Blank records for evidence-led diagnosis

A. Initial observation record

Field	Record
Date / time	
Facility / room / zone	
Cultivar / accession	
Plant or batch ID	
Growth stage / days from transition	
Symptom first noticed	
First affected tissue	
Pattern and direction of progression	
Recent nutrient, irrigation or environmental change	
Photograph IDs / links	

B. System verification

Field	Record
Recipe ID / version	
Water profile / sample date	
Dose / injector setting	
Feed pH / EC / temperature	
Drain or reservoir pH / EC / temperature	
Drain fraction or reservoir volume	
Root appearance / odour / oxygen	
Air / leaf / root-zone temperature	
RH / leaf VPD	
PPFD / photoperiod / DLI	
Meter IDs / calibration dates	

C. Hypothesis comparison

Hypothesis	Evidence for	Evidence against	Test / sample
Hypothesis 1			
Hypothesis 2			
Hypothesis 3			

D. Controlled change and follow-up

Field	Record
Variable changed	
Reason / supporting result	
Control retained	
Date and exact change	
Expected response window	
New-growth observation	
Measured growth / biomass / yield response	
Feed/drain/tissue follow-up	
Decision	

References

Primary scientific sources

Numbered citations in the handbook refer to the sources below. DOI links are included so the version of record can be checked directly. [1,2]

1. Cockson P, Landis H, Smith T, Hicks K, Whipker BE. Characterization of Nutrient Disorders of Cannabis sativa. Applied Sciences. 2019;9:4432. https://doi.org/10.3390/app9204432
2. Llewellyn D, Golem S, Jones AMP, Zheng Y. Foliar Symptomology, Nutrient Content, Yield, and Secondary Metabolite Variability of Cannabis Grown Hydroponically with Different Single-Element Nutrient Deficiencies. Plants. 2023;12:422. https://doi.org/10.3390/plants12030422
3. Landis H, Hicks K, Cockson P, Henry JB, Smith JT, Whipker BE. Expanding Leaf Tissue Nutrient Survey Ranges for Greenhouse Cannabidiol-Hemp. Crop, Forage & Turfgrass Management. 2019;5:180081. https://doi.org/10.2134/cftm2018.09.0081
4. Kalinowski J, Edmisten K, Davis J, et al. Augmenting Nutrient Acquisition Ranges of Greenhouse Grown CBD Hemp Cultivars. Horticulturae. 2020;6:98. https://doi.org/10.3390/horticulturae6040098
5. Saloner A, Bernstein N. Response of Medical Cannabis (Cannabis sativa L.) to Nitrogen Supply Under Long Photoperiod. Frontiers in Plant Science. 2020;11:572293. https://doi.org/10.3389/fpls.2020.572293
6. Saloner A, Sacks MM, Bernstein N. Response of Medical Cannabis Genotypes to K Supply Under Long Photoperiod. Frontiers in Plant Science. 2019;10:1369. https://doi.org/10.3389/fpls.2019.01369
7. Shiponi S, Bernstein N. The Highs and Lows of P Supply in Medical Cannabis: Effects on Cannabinoids, the Ionome, and Morpho-Physiology. Frontiers in Plant Science. 2021;12:657323. https://doi.org/10.3389/fpls.2021.657323
8. Saloner A, Bernstein N. Effect of Potassium Supply on Cannabinoids, Terpenoids and Plant Function in Medical Cannabis. Agronomy. 2022;12:1242. https://doi.org/10.3390/agronomy12051242
9. Saloner A, Bernstein N. Nitrogen Source Matters: High NH4/NO3 Ratio Reduces Cannabinoids, Terpenoids, and Yield in Medical Cannabis. Frontiers in Plant Science. 2022;13:830224. https://doi.org/10.3389/fpls.2022.830224
10. Morad D, Bernstein N. Response of Medical Cannabis to Magnesium Supply at the Vegetative Growth Phase. Plants. 2023;12:2676. https://doi.org/10.3390/plants12142676
11. Morad D, Bernstein N. From Deficiency to Toxicity: Magnesium Increases Cannabinoid and Terpene Production in Cannabis Plants. Journal of Cannabis Research. 2025;7:103. https://doi.org/10.1186/s42238-025-00358-9
12. Shiponi S, Bernstein N. The Power of Zinc: Excess and Deficiency of Zn Decrease Cannabinoids in Cannabis Without Zn Toxicity Concerns to Consumers. Journal of Cannabis Research. 2026;8:33. https://doi.org/10.1186/s42238-026-00404-0
13. Cockson P, Schroeder-Moreno M, Veazie P, et al. Impact of Phosphorus on Cannabis sativa Reproduction, Cannabinoids, and Terpenes. Applied Sciences. 2020;10:7875. https://doi.org/10.3390/app10217875
14. Veazie P, Cockson P, Logan D, Whipker BE. Magnesium's Impact on Cannabis sativa 'BaOx' and 'Suver Haze' Growth and Cannabinoid Production. Journal of Agricultural Hemp Research. 2021;2(2):1. https://doi.org/10.61611/2688-5182.1018
15. Veazie P, Cockson P, Jackson B, Hicks K, Whipker BE. Impact of Substrate pH and Micronutrient Fertility Rates on Cannabis sativa. Agrosystems, Geosciences & Environment. 2025;8:e70044. https://doi.org/10.1002/agg2.70044
16. Bevan L, Jones M, Zheng Y. Optimisation of Nitrogen, Phosphorus, and Potassium for Soilless Production of Cannabis sativa in the Flowering Stage Using Response Surface Analysis. Frontiers in Plant Science. 2021;12:764103. https://doi.org/10.3389/fpls.2021.764103
17. Westmoreland FM, Bugbee B. Sustainable Cannabis Nutrition: Elevated Root-Zone Phosphorus Significantly Increases Leachate P and Does Not Improve Yield or Quality. Frontiers in Plant Science. 2022;13:1015652. https://doi.org/10.3389/fpls.2022.1015652
18. Hershkowitz JA, Westmoreland FM, Bugbee B. Elevated Root-Zone P and Nutrient Concentration Do Not Increase Yield or Cannabinoids in Medical Cannabis. Frontiers in Plant Science. 2025;16:1433985. https://doi.org/10.3389/fpls.2025.1433985
19. Kpai PY, Adaramola O, Addo PW, MacPherson S, Lefsrud M. Mineral Nutrition for Cannabis sativa in the Vegetative Stage Using Response Surface Analysis. Frontiers in Plant Science. 2024;15:1501484. https://doi.org/10.3389/fpls.2024.1501484
20. Dilena E, Hunt I, Close DC. Optimal Nitrogen Rates and Clonal Effects on Cannabinoid Yields in Medicinal Cannabis. Scientific Reports. 2025;15:12341. https://doi.org/10.1038/s41598-025-96761-6
21. Massuela DC, Munz S, Hartung J, Nkebiwe PM, Graeff-Hönninger S. Cannabis Hunger Games: Nutrient Stress Affects Biomass and Cannabinoid Concentration Differently. Frontiers in Plant Science. 2023;14:1233232. https://doi.org/10.3389/fpls.2023.1233232
22. Ahrens A, Llewellyn D, Zheng Y. Is Twelve Hours Really the Optimum Photoperiod for Promoting Flowering in Indoor-Grown Cultivars of Cannabis sativa? Plants. 2023;12:2605. https://doi.org/10.3390/plants12142605
23. Ahrens A, Llewellyn D, Zheng Y. Longer Photoperiod Substantially Increases Indoor-Grown Cannabis' Yield and Quality: 12 h vs. 13 h Days. Plants. 2024;13:433. https://doi.org/10.3390/plants13030433
24. Grover EF, Haiden SR, Berkowitz GA. Examining the 'Night Break' Method in Cannabis sativa Horticulture: Vegetative Daily Light Integral Affects Yield of Extractable Biomass. Plants. 2025;14:3095. https://doi.org/10.3390/plants14193095

25. Corredor-Perilla IC, Kwon TH, Park SH. Elevated Relative Humidity Significantly Decreases Cannabinoid Concentrations While Delaying Flowering Development in Cannabis sativa L. Frontiers in Plant Science. 2025;16:1678142. https://doi.org/10.3389/fpls.2025.1678142

26. Holweg MMSF, Curren T, Cravino A, et al. High Air Temperature Reduces Plant Specialized Metabolite Yield in Medical Cannabis, and Has Genotype-Specific Effects on Inflorescence Dry Matter Production. Environmental and Experimental Botany. 2025;230:106085. https://doi.org/10.1016/j.envexpbot.2025.106085

27. Buirs L, Punja ZK. Integrated Management of Pathogens and Microbes in Cannabis sativa L. under Greenhouse Conditions. Plants. 2024;13:786. https://doi.org/10.3390/plants13060786

28. Adkar-Purushothama CR, Sano T, Perreault JP. Hop Latent Viroid: A Hidden Threat to the Cannabis Industry. Viruses. 2023;15:681. https://doi.org/10.3390/v15030681

29. Punja ZK, Collyer D, Scott C, Lung S, Holmes J, Sutton D. Pathogens and Molds Affecting Production and Quality of Cannabis sativa L. Frontiers in Plant Science. 2019;10:1120. https://doi.org/10.3389/fpls.2019.01120

30. Marschner P, ed. Marschner's Mineral Nutrition of Higher Plants. 3rd ed. Academic Press; 2012. https://doi.org/10.1016/C2009-0-63043-9

31. Bugbee B. Nutrient Management in Recirculating Hydroponic Culture. Acta Horticulturae. 2004;648:99-112. https://doi.org/10.17660/ActaHortic.2004.648.12

32. Backer R, Schwinghamer T, Rosenbaum P, et al. Closing the Yield Gap for Cannabis: A Meta-Analysis of Factors Determining Cannabis Yield. Frontiers in Plant Science. 2019;10:495. https://doi.org/10.3389/fpls.2019.00495

33. Rodriguez-Morrison V, Llewellyn D, Zheng Y. Cannabis Yield, Potency, and Leaf Photosynthesis Respond Differently to Increasing Light Levels in an Indoor Environment. Frontiers in Plant Science. 2021;12:646020. https://doi.org/10.3389/fpls.2021.646020

34. Yep B, Gale NV, Zheng Y. Aquaponic and Hydroponic Solutions Modulate NaCl-Induced Stress in Drug-Type Cannabis sativa L. Frontiers in Plant Science. 2020;11:1169. https://doi.org/10.3389/fpls.2020.01169

35. Saloner A, Bernstein N. Nitrogen Supply Affects Cannabinoid and Terpenoid Profile in Medical Cannabis. Industrial Crops and Products. 2021;167:113516. https://doi.org/10.1016/j.indcrop.2021.113516

36. Bernstein N, Gorelick J, Zerahia R, Koch S. Impact of N, P, K, and Humic Acid Supplementation on the Chemical Profile of Medical Cannabis. Frontiers in Plant Science. 2019;10:736. https://doi.org/10.3389/fpls.2019.00736

37. Panday D, et al. Precision Nitrogen Management for Optimal Yield and Cannabinoid Profile in CBD Hemp Agronomy. Agrosystems, Geosciences & Environment. 2025;8:e70028. https://doi.org/10.1002/agg2.70028

Supplementary practical reading

The following industry articles are included as accessible diagnostic companions. They are not used as the sole authority for any technical claim in this handbook; primary studies remain the evidentiary basis. [1,13,14,15]

P1. Brian Whipker, James Turner Smith, Paul Cockson and Hunter Landis. Yellowing Leaves?. Cannabis Business Times.

P2. Paul Cockson, Patrick Veazie and Brian E. Whipker. Teasing Out Mimics: Potassium vs. Magnesium. Cannabis Business Times.

P3. Patrick Veazie, Paul Cockson and Brian E. Whipker. Feel the (Cannabis Leaf Margin) Burn. Cannabis Business Times.

P4. Brian Whipker, James T. Smith, Paul Cockson and Hunter Landis. Magnesium: Part of a Balanced Cannabis Diet. Cannabis Business Times.

P5. Paul Cockson, Michelle Schroeder-Moreno, Patrick Veazie, David Logan and Brian E. Whipker. How to Optimize Phosphorus Fertility for Cannabis. Cannabis Business Times.

Document note

The cover illustration and all diagrams in this handbook are original editorial artwork prepared for this edition and synthesised from the cited literature. They do not reproduce third-party photographs or figures. Literature review cut-off: 6 August 2026.