Understanding the Right Nitrogen Form Ammonium versus Nitrate, Source, Rate, Timing and Placement of Nutrients and Conservation for Container Grown Plants

- Dharma Pitchay, PhD
- College of Agriculture,
- Tennessee State University
- dpitchay@tnstate.edu
- Tel. 615 963 4890 or cell 419 973 3762

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Should Ammonium (NH_4) & Nitrate (NO_3) be treated as separate nutrients?

NH^+_4 NO^-_3

N	P	K	Ca	Mg	S
Nitrogen 14	Phosphorus 31	Potassium 39	Calcium 40	Magnesium 24	Sulfur 32

MACRONUTRIENTS

B	Cl	Mn	Fe
Boron 10.8	Chlorine 35.5	Manganese 55	Iron 55.8

Ni	Cu	Zn	Mo
Nickel 58.7	Copper 63.5	Zinc 65.4	Molybdenum 96

MICRONUTRIENTS

H	C	O
Hydrogen 1	Carbon 12	Oxygen 16

Non- Fertilizer Elements

Why is it critical to choose the right N Form & Source?

- Excellent Crop Performance
- Significant Reduction in Nutrient leachate & Run-off
- Protecting the Environment – Greenhouse Gases
- Conservation of Resources
- Sustainability

Why Implementing the 4R principles is challenging in Nursery/Greenhouse industry?

- No single set of correct practices that can be universally adopted
- Grower make decisions based on available resources suited to crop requirements & local conditions
- Adjusting practices for each species is challenging
- Decision based on field, substrate type, water quality, production targets, weather conditions, economic and environmental factor
- Species and Nursery conditions determine the appropriate 4R practices of nutrient management decisions

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For Optimum Plant Growth:

Nitrogen is widely applied for plant growth

Nitrogen is also the fertilizer applied in large quantities than the rest of plant mineral nutrient

- Make sure maximum amount of N nutrient is taken up by plants
- Apply the right form of N
- Right Nitrogen source
- It should be in the readily soluble form
- It should be in the available ionic form for plant uptake

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Can 4R nutrient stewardship be practiced using single nutrient formulation in container production?

Yes – monocrop

No - multiple crops

- Classify plant species based on NO_3 or NH_4 preference
- Identify the species in the production area
- Separate and Group the species according to N form needs
- Place the species in the production site that fits with species requirements and availability
- Delivere Specific NO_3 or NH_4 plus the remaining essential nutrients based on 4R nutrient stewardship

What do we know about Nitrogen Form - NH_4 vs. NO_3?

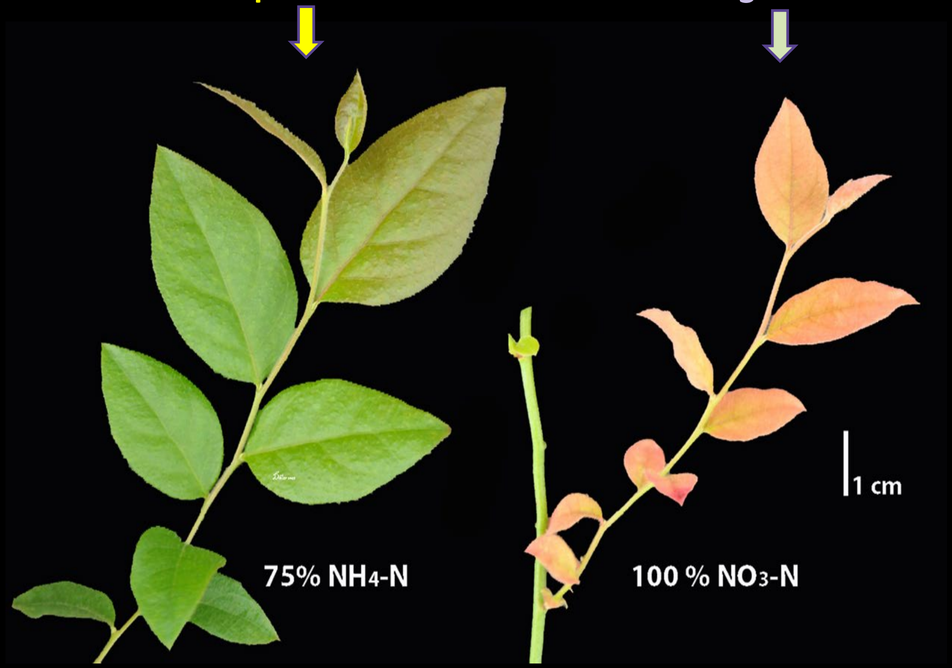
- Nitrogen forms have significant influence on the overall uptake and assimilation of essential mineral elements, especially the anions & cations
- Current challenge is not specifying the crop specific N form requirement
- Plants' association to N fixing Rhizobium bacteria cease to colonize and N fixation is halted when there is an excess of NO_3-N is present
- Therefore, the NH_4 and NO_3 need to be treated differently
- Plants' geographical origin and genetic requirement are overlooked
- Current production practices tailored towards >50 species under a single nutrient regime operation and environmental condition

Nitrogen Form - NH_4 vs. NO_3

- **Form of N (NH_4 vs. NO_3) availability limit the plant growth in container production**
- **These two ions differ significantly in their chemical properties**
  - **E.g., NH_4 => cation**
    - ➢ **Promotes the uptake of anions PO_4, and SO_4**
    - ➢ **but suppresses cation uptake of K, Ca, Mg etc.**
    - ➢ **Acidifies the rhizosphere**

  NO_3 => anion
    - ➢ **Promotes the uptake of cations K, Ca, Mg etc.**
    - ➢ **but suppresses cation uptake of PO_4 and SO_4 etc.**
    - ➢ **Raises the rhizosphere pH**
    - ➢ **Water soluble**

75% NH_4-N Form **100 NO_3-N Form**



Plant's response differ depending on N form

Growing nursery/greenhouse plants in containers

Unique plant production system using soilless substrate compared to field crops grown in soil

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Greenhouse/ Nursery operations and management are classified - intensive agricultural systems

Producing Several Millions of different Species

4R NUTRIENT STEWARDSHIP

RIGHT NUTRIENT SOURCE

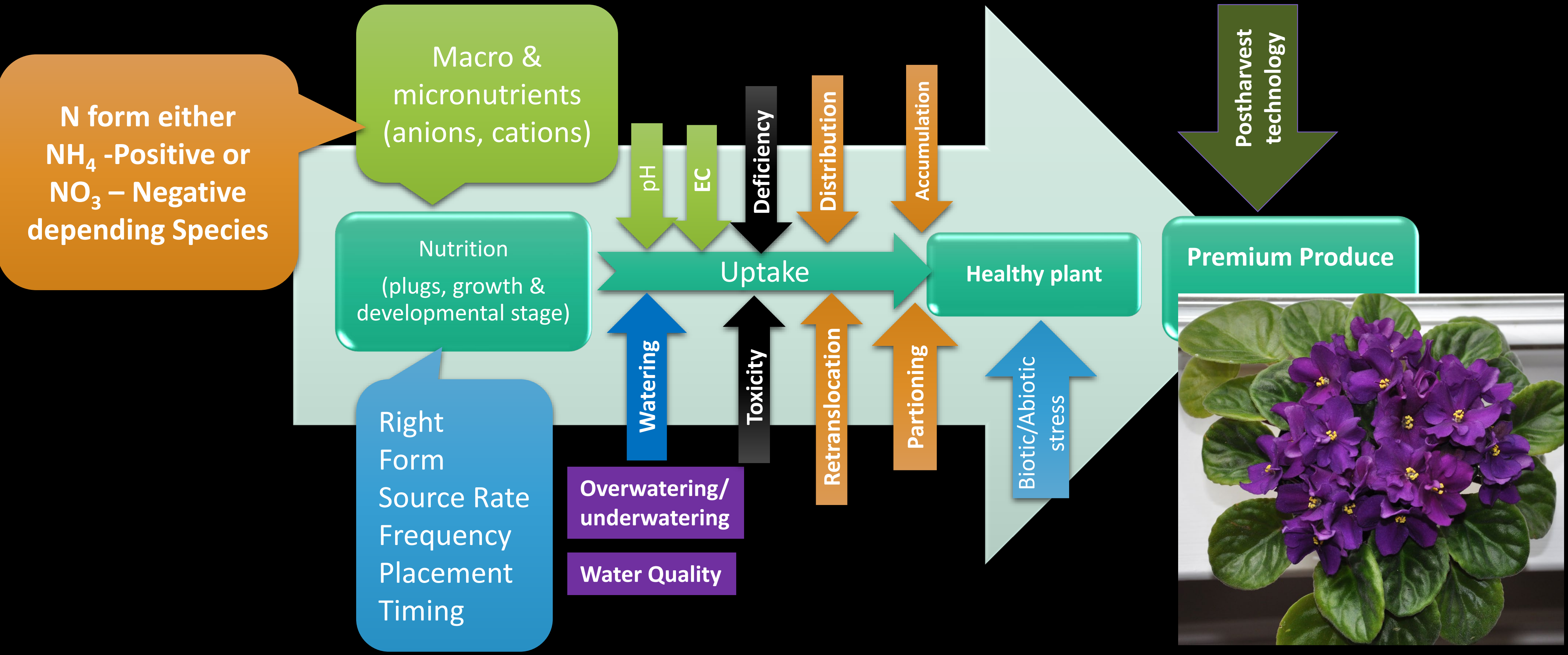
RATE

DELIVERY

TIMING

FOR OPTIMAL GROWTH & CONSERVATION PRACTICES

Nutrient Management in container production





Nutrient and water management Challenges

Nutrient and Water Management Challenges

Uniform delivery of adequate amount of water for optimum plant growth development

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WATERING:

- **meeting crop water demands - crop cooling, & frost   protection**

- **Non-targeted water placement**

- **Water is added in excess of substrate water-holding capacity results in downward nutrient leachate**

Selection of Nitrogen fertilizer - form and source

- Species Specific Nitrogen Nutrient Requirement
- Accompanying anion/cation present in Nitrogen Fertilizer
- Type of Substrate
- Water quality
- Economic Factor - Cost
- Potential losses to environment

NH_4-N preferred species

Melastomataceae

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Conifer

Juniperus

Chamaecyparis


Thuja


YEW


Pinus


Ilex


Laurel
(Prunus laurocerasus)
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Boxwood


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Pyracantha

Callistemon

Camelia

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Rhododendron

Kalmia latifolia

Viburnum

NO_3-N preferred species


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Categorization of NH_4 versus NO_3- N Preferred Species

Ammonium	Nitrate
Evergreen	Deciduous
Acidic Rhizosphere	Near neutral Rhizosphere
Tolerant of Anaerobic condition	Aerobic rhizosphere
Tolerant of wet substrate	Less tolerant of wet substrate
Cooler environment	Warmer environment
Less vigorous growth habit	Vigorous growth habit

Conservation Practices in container Production

Require precise & properly timed applications of N form, source & rate for maximum benefits & minimum resources risk.

NO_3 preferred species

NH_4 preferred species

Species with rhizobium association

- Species –
  - ✓ NH_4 vs. NO_3 preferred species
  - ✓ Microbial symbiosis – Rhizobium vs Mycorrhizae
- Irrigation water - Alkalinity
- Fertilizers – Acidic vs. Basic
- Substrate – Acidic vs. Basic
- Calcium source – Lime vs. Gypsum
- Temperature High: $NH_4 \rightarrow NH_3$

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Physical, Chemical and Biological Properties
of the soil need to be improved before growing

Complex & Heterogeneity

Soil composition – Percent organic matter?
% clay?
% aggregates?
Cation exchange capacity?
Water holding capacity?
Physical & chemical properties?

Soilless Substrate - Physical and Chemical Properties

Buffering →

CEC / AEC → **Minimal**

	Coir	Peat	Fresh PineBark	Aged PineBark
pH	6.0 - 7.2	3.0 – 3.5	5.0	5.2
EC	*1.2 – 2.1*	*0.1 - 0.2*	*0.1- 0.2*	*0.2-0.3*

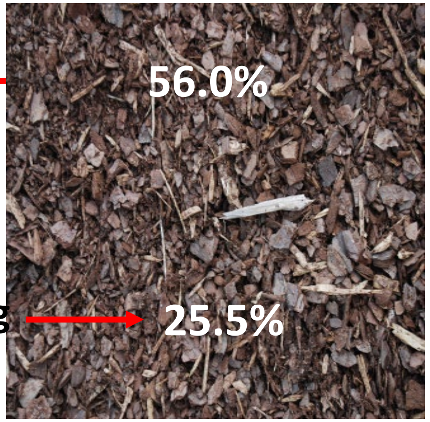
Coir

Peat

Difference

Total Porosity → 81.0% — 15% → 66.0%

Air Capacity

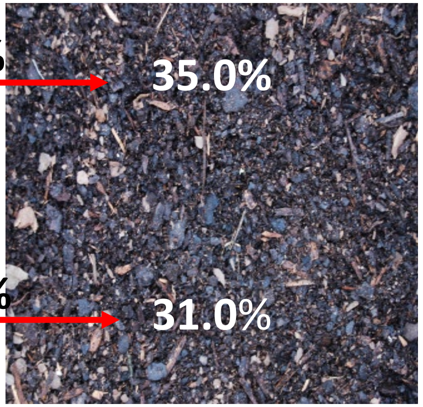


Water-holding Capacity

Fresh PineBark

21%

5.5%



Aged PineBark

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Factors influencing Rhizosphere pH

During Potting

1. Substrate
   a. Coir ➔ Raise pH value
   b. Peat ➔ Lower pH value
   c. Pinebark ➔ Lower pH value
2. Calcium sources:
   a. liming materials – CaOH, $CaCO_3$ etc., ➔ Raise pH value
   b. Gypsum – $CaSO_4$ ➔ Somewhat lower pH value

During Production

3. Water Quality: Irrigation water
   a. Acidic ➔ Lower pH value
   b. Alkalinity ➔ Raise pH value
4. Nitrogen Sources – during production
   a. Ammonium Form ➔ Lower pH value
   b. Nitrate Form – Raise pH value
   c. Ammonium: Nitrate (1:1) Form ➔ Lower pH value

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Conservation Practices in container Production

Require precise & properly timed applications of N form, source & rate for maximum benefits & minimum resources risk.

NO_3 preferred species

NH_4 preferred species

- Species –
  - ✓ Ammonium vs. Nitrate preferred species
  - ✓ Microbial symbiosis – Rhizobium vs Mycorrhizae
- Irrigation water - Alkalinity
- Fertilizers – Acidic vs. Basic
- Substrate – Acidic vs. Basic
- Calcium source – Lime vs. Gypsum
- Temperature High: $NH_4 \rightarrow NH_3$

Species with rhizobium association

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Nitrate(NO_3) preferred species

Root growth & development in response to different ratios of NH_4:NO_3

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Common fig grown under five NH_4^+: NO_3^- ratios left to right: 0:100, 25:75, 50:50, 75:25 and 100:0.

Knockout roses grown under five NH_4^+: NO_3^- ratios left to right: 0:100, 25:75, 50:50, 75:25 and 100:0.

Rosaceae

pH 5.8 to 6.8

EC < 2

Optimal pH conditions:
Apply fertilizer as needed
(Right rate: 200 -250 ppm of using 75% NO_3-N & 25% NH_4-N)

pH < 5.8

EC < 2

1. Add lime
2. Rate 200 - 250 ppm
3. Add multi-nutrient fertilizers that do not contain Sulfur or Ammonium based Nitrogen.

EC > 2

1. Add lime
2. Leach to remove excess salts
3. Apply **fertilizers** that do not contain sulfur or Ammonium based Nitrogen.

pH ≥ 6.8

EC < 2

1. Acidify the water
2. Add multi-nutrient Acidic fertilizers that contain sulfur or Ammonium based Nitrogen & NOT NO_3-N

EC > 2

1. Leach to remove excess salts.
2. Apply fertilizers that contain sulfur or ammonium based nitrogen.

Ericaceae

MONITORING AND MANAGING
Substrate pH, EC and Nutrients

pH 5.5 to 6.0

EC < 2

Optimal pH conditions
Apply fertilizer as needed
(Right rate: 150-200 ppm using 75% NH_4-N and 25% NO_3-N)

pH < 5.5

EC < 2

1. Add lime ($CaOH_2$)
2. Right rate 200-250 ppm
3. Add multi-nutrient fertilizers that do not contain sulfur of NH_4-N

EC > 2

1. Add lime ($CaOH_2$)
2. Leach to remove excess salts
3. Apply fertilizers (100 ppm) that do not contain sulfur or NH_4-N

pH > 6.0

EC < 2

1. Add multi-nutrient acidic fertilizers that contain sulfur or NH_4-N NOT NO_3-N
2. Inject acid (vinegar or sulfuric acid) to water

EC > 2

1. Leach to remove excess salts
2. Apply fertilizers (100 ppm) that contain sulfur or NH_4-based N
3. Inject acid (vinegar or sulfuric acid) to water

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Fe requirement is greater in NO_3 preferred species than NH_4– N form

- Ensure availability of Sufficient Iron
- Fe is needed to convert NO_3 – Amino acid:

- NO_3 => NO_2 + Ferredoxin (red^n/Oxd^n) => NH_4 =>Glutamate

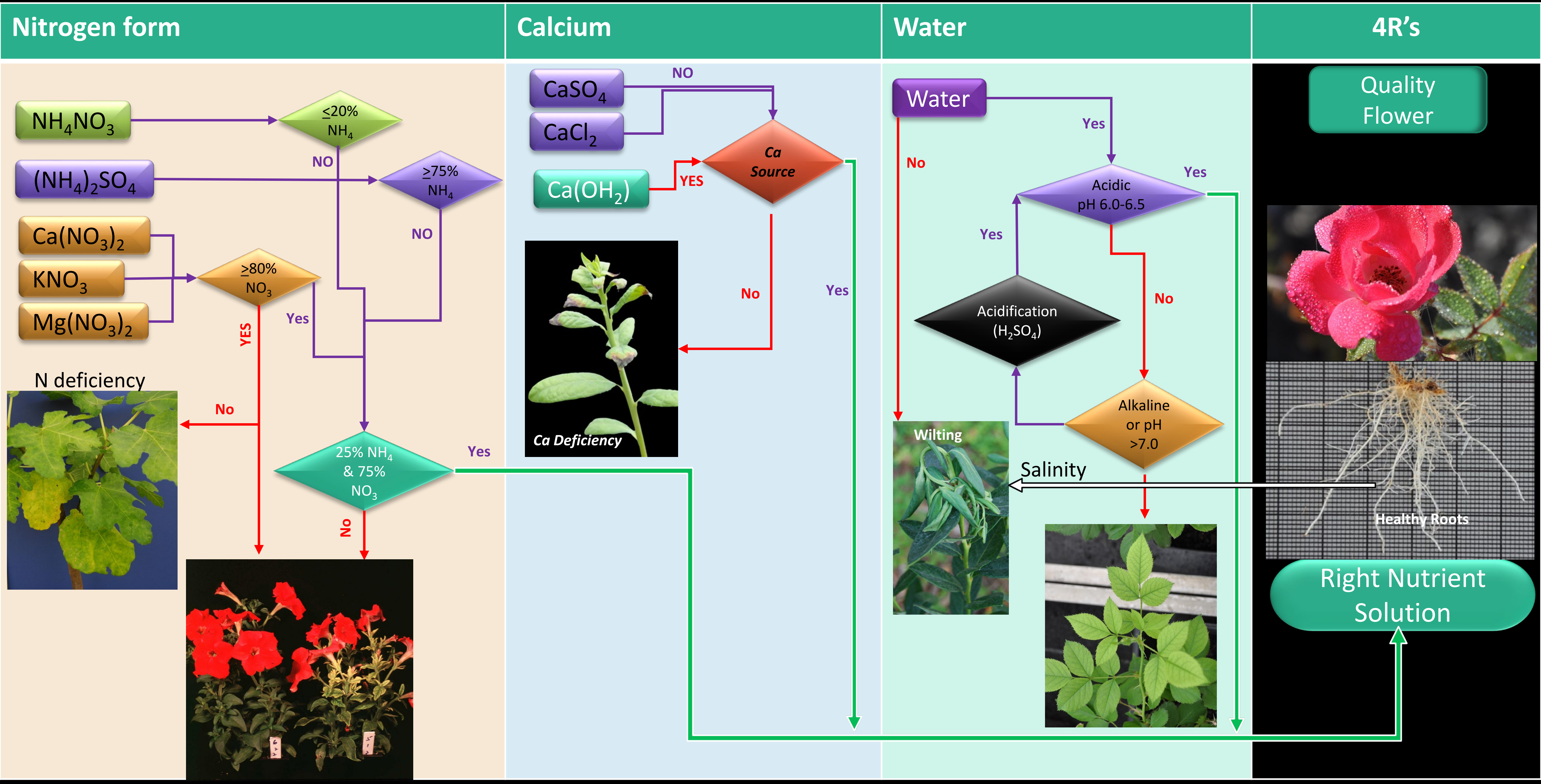
Plants are prone to Fe deficiency

- Demand & Requirement for Fe is greater
- An increase pH value due to NO_3 uptake
- Anerobic condition – poor water management

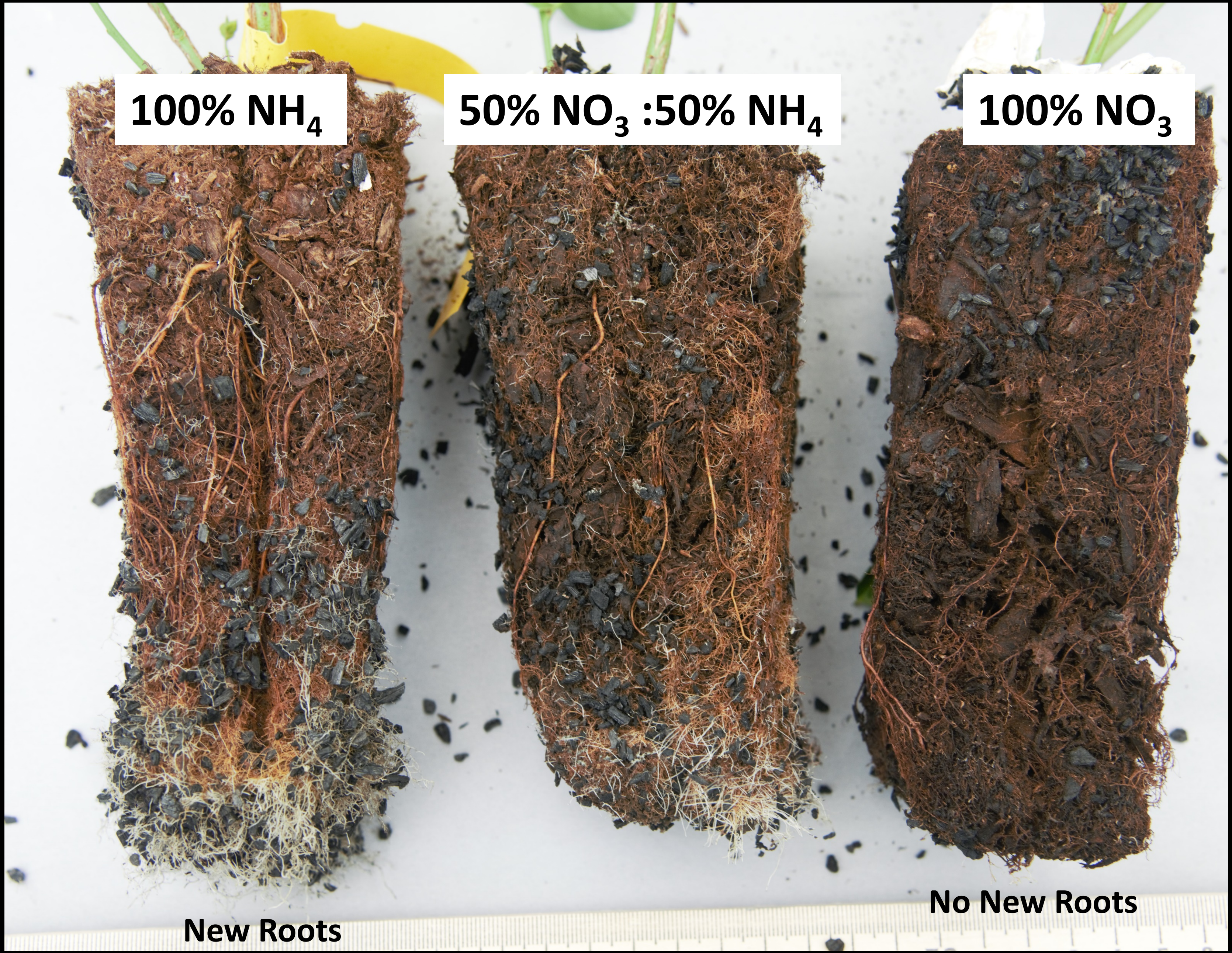
Normal

Iron deficient

4R Nutrient Stewardship: Right Source; Rate; Timing; Right Method for NO_3 Preferred Species



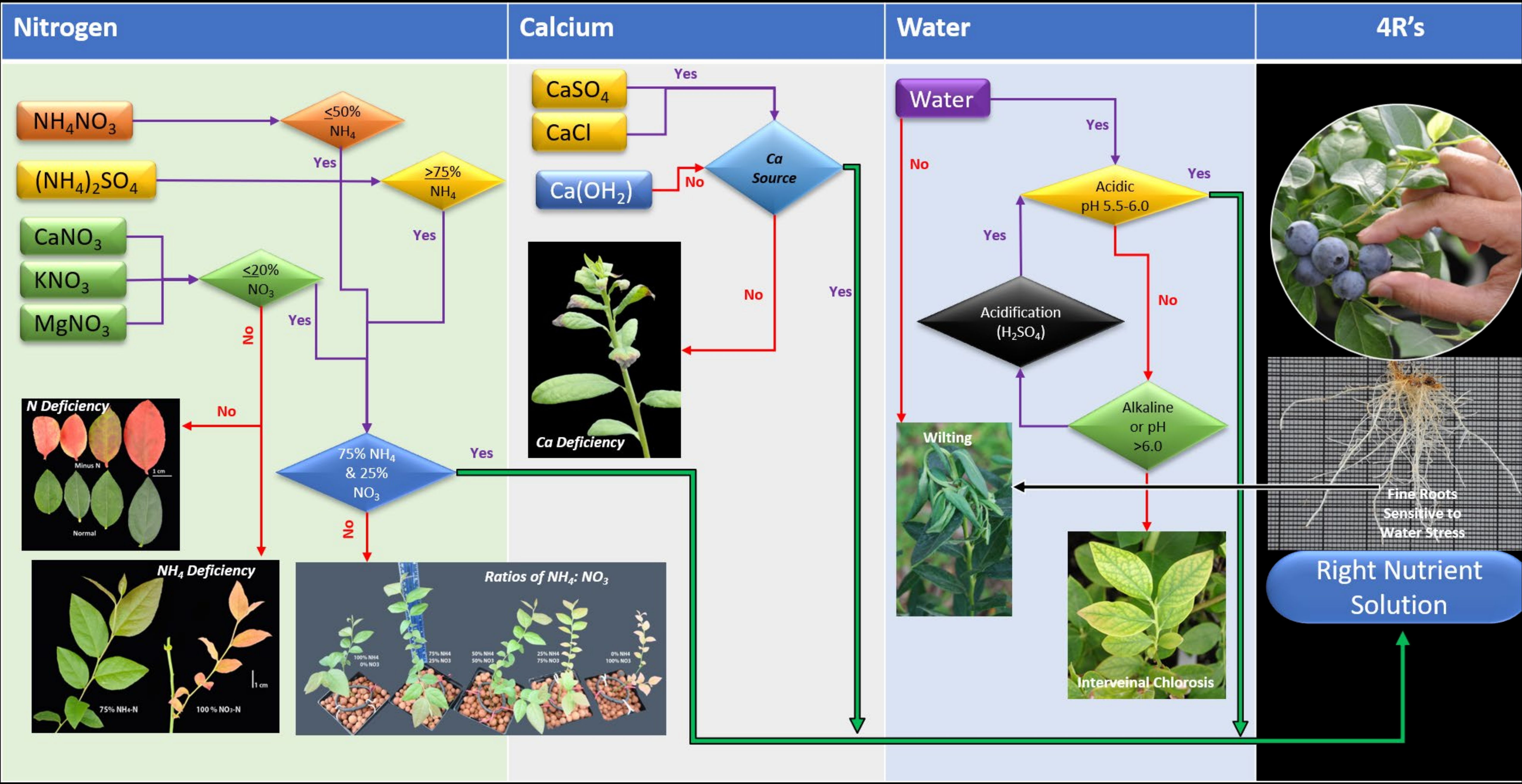
Ammonium – N preferred Species

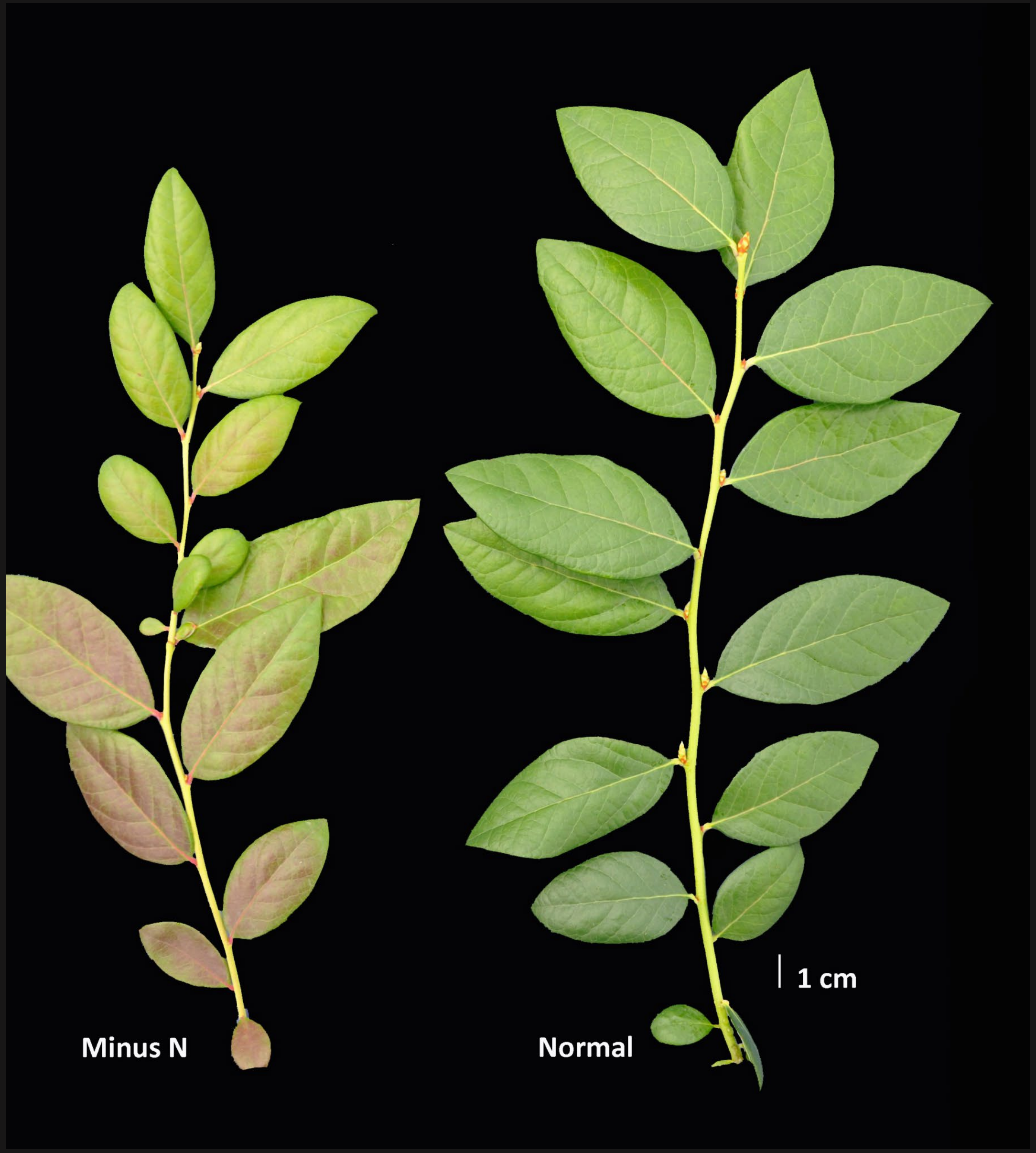


The Form of Nitrogen supply is critical

- Species that prefer NH_4 form of N than the NO_3 form of N
- The ammonium source should be greater than 75% of the total N in the fertilizer
- It is critical to look for the N source in the fertilizer bags before applying fertilizers
- Minimize the application of fertilizer sources such as $CaNO_3$, KNO_3or $NaNO_3$.
- Liming of soil is not recommended
- $CaSO_4$ – excellent Ca source

NH_4-N Preferred Species: 4R Nutrient Stewardship: Right Source; Rate; Timing; Method



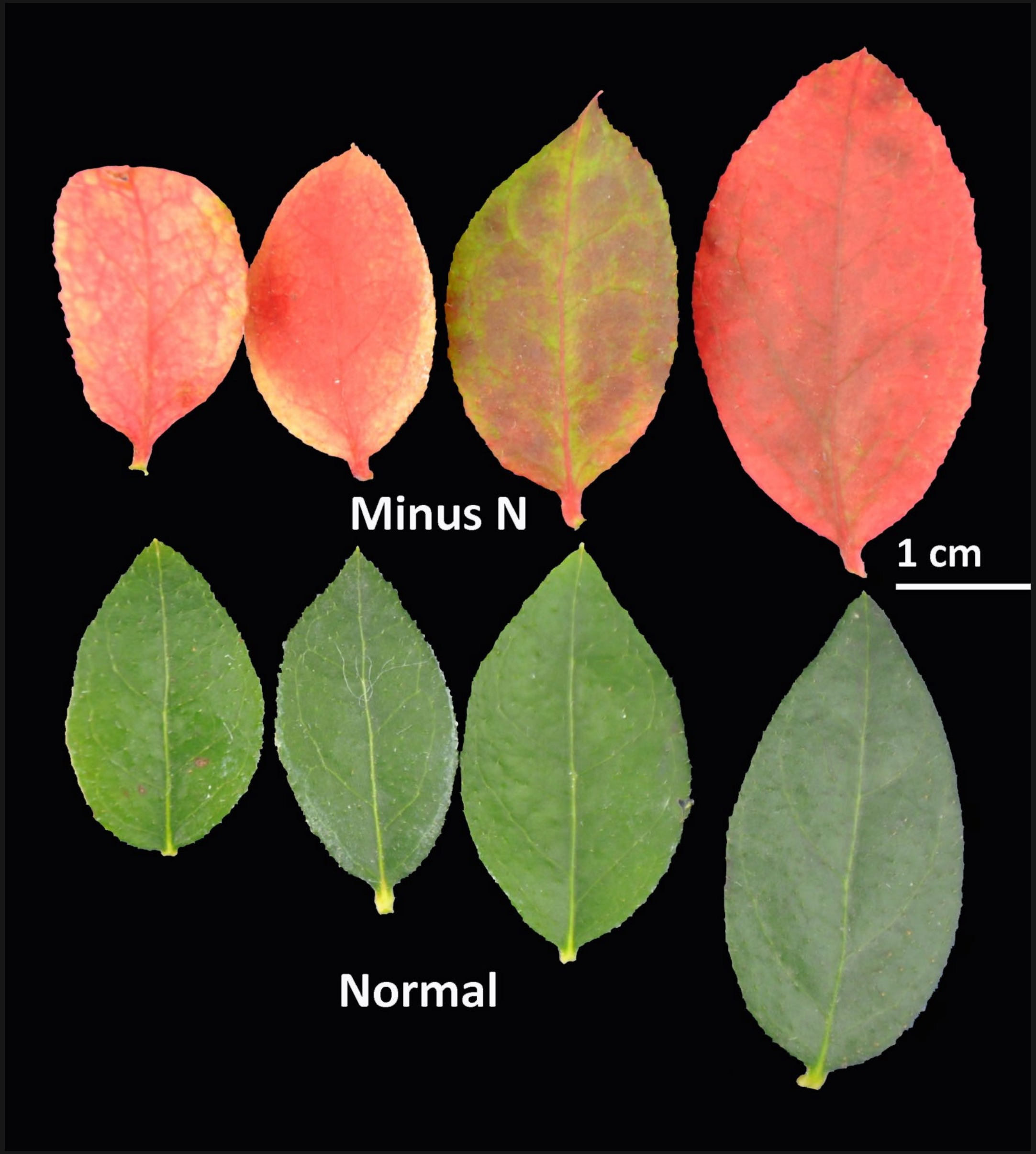


Disruption of nitrogen supply & uptake at initial stage

- *Visual symptoms of Nitrogen deficiency - light chlorosis & development of red pigmentation on lower older leaves*

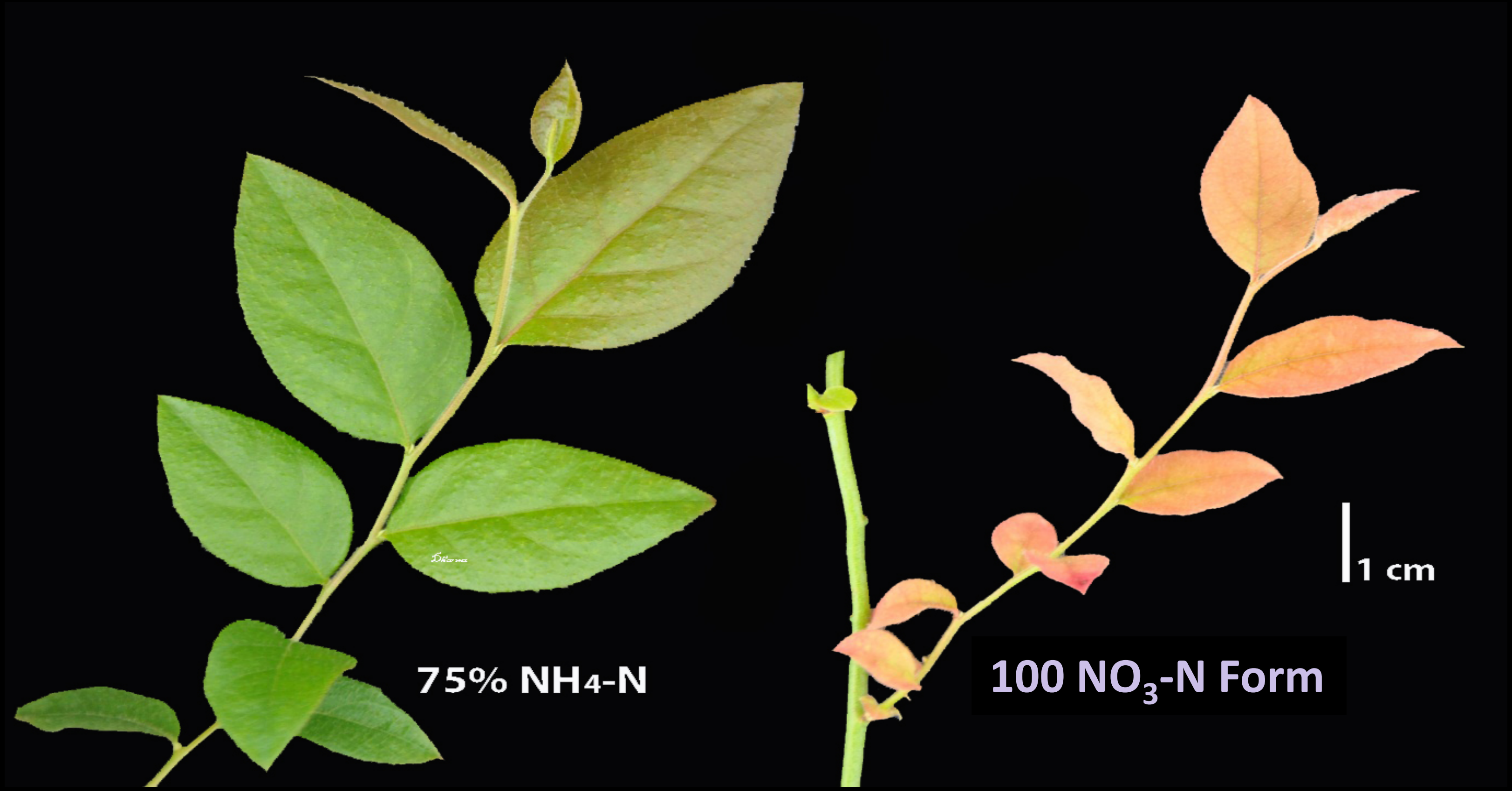
Severe Disruption of nitrogen supply & uptake for an extended period

- *Obvious Nitrogen deficiency symptoms as the entire leaf blade of lower older leaves turn red/pink & petiole*



Selection of Nitrogen form is critical
NH_4 –N preferred Species

Nitrogen deficiency as a result of inappropriate form of nitrogen application



UREA as a Nitrogen source for Ericaceae species

- ✓ First Urea has to be converted to NH_4 form before it can be taken up by the roots.
- ✓ For that substrate pH has to be monitored and managed properly if not the NH_4 can be converted to Ammonia (NH_3)
- ✓ Ammonia is a gas and it is toxic to most plants
- ✓ pH should be below 6.8

Visual symptoms of Ammonia (NH_3) Toxicity

Substrate pH and N form - critical factor for color manipulation

- *NH_4-N source will increase Al uptake – Blue flowers*
- *NO_3-N source will lower Al uptake – Pink Flowers*
- *High pH reduces the availability of Al*
  - ✓ *Water alkalinity*
  - ✓ *Substrate type*

Hydrangea flower color manipulation

Al 3959 mg/Kg dry wt.

804 mg/Kg dry wt.

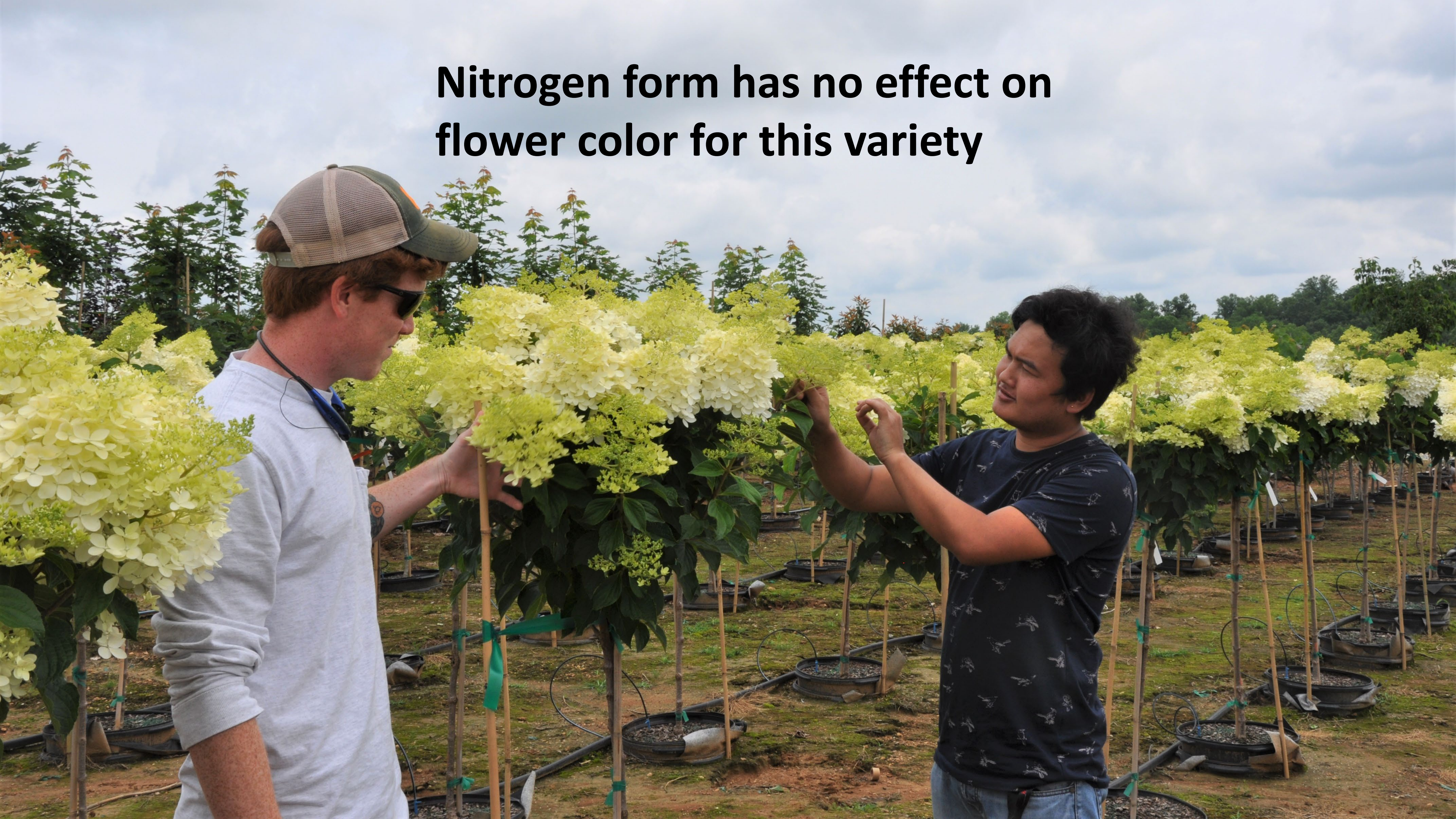
640 mg/Kg dry wt.

51 mg/Kg dry wt.

0.0 mg/Kg dry wt.

- NH_4-N source will increase Al uptake – Blue flowers
- NO_3-N source will lower Al uptake – Pink Flowers

Nitrogen form has no effect on flower color for this variety



Influence of NO_3 rates on Flowering

Plant's response differ depending on NO_3 rate

Categorization of Ammonium versus Nitrate- nitrogen Preferred Species

Ammonium	Nitrate
Evergreen	Deciduous
Acidic Rhizosphere	Near neutral Rhizosphere
Tolerant of Anaerobic condition	Aerobic rhizosphere
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Cooler environment	Warm environment
Less vigorous growth habit	Vigorous growth habit

Should NH_4 & NO_3 be treated as separate nutrients?

NH_4^{+}

NO_3^{-}

N Nitrogen 14	P Phosphorus 31	K Potassium 39	Ca Calcium 40	Mg Magnesium 24	S Sulfur 32

MACRONUTRIENTS

B Boron 10.8	Cl Chlorine 35.5	Mn Manganese 55	Fe Iron 55.8			
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Non- Fertilizer Elements

Why choosing the right N Form & Source is critical?

Excellent Crop Performance

Significant Reduction in Nutrient leachate & Run-off

Protecting the Environment – Greenhouse Gases

Conservation of Resources

Sustainability

Thank you

For additional Information please visit:

https://www.tnstate.edu/4rconservation/

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