



# 芝生の管理に必要な 土壌学・肥料学の基礎

## 異常気象時代の管理

2016静岡県コース管理研修会  
株式会社ヒューエンタープライズ

Simplot

# 異常気象とは

- 短時間の集中的豪雨
- 気温（夏の高温・冬の温暖）

# 対策

- 水の排水性
- 養分管理
- 疎水性土壌の管理（浸透剤）
- スプリンクラーの設定
- 芝密度の維持

# 地上部の成長

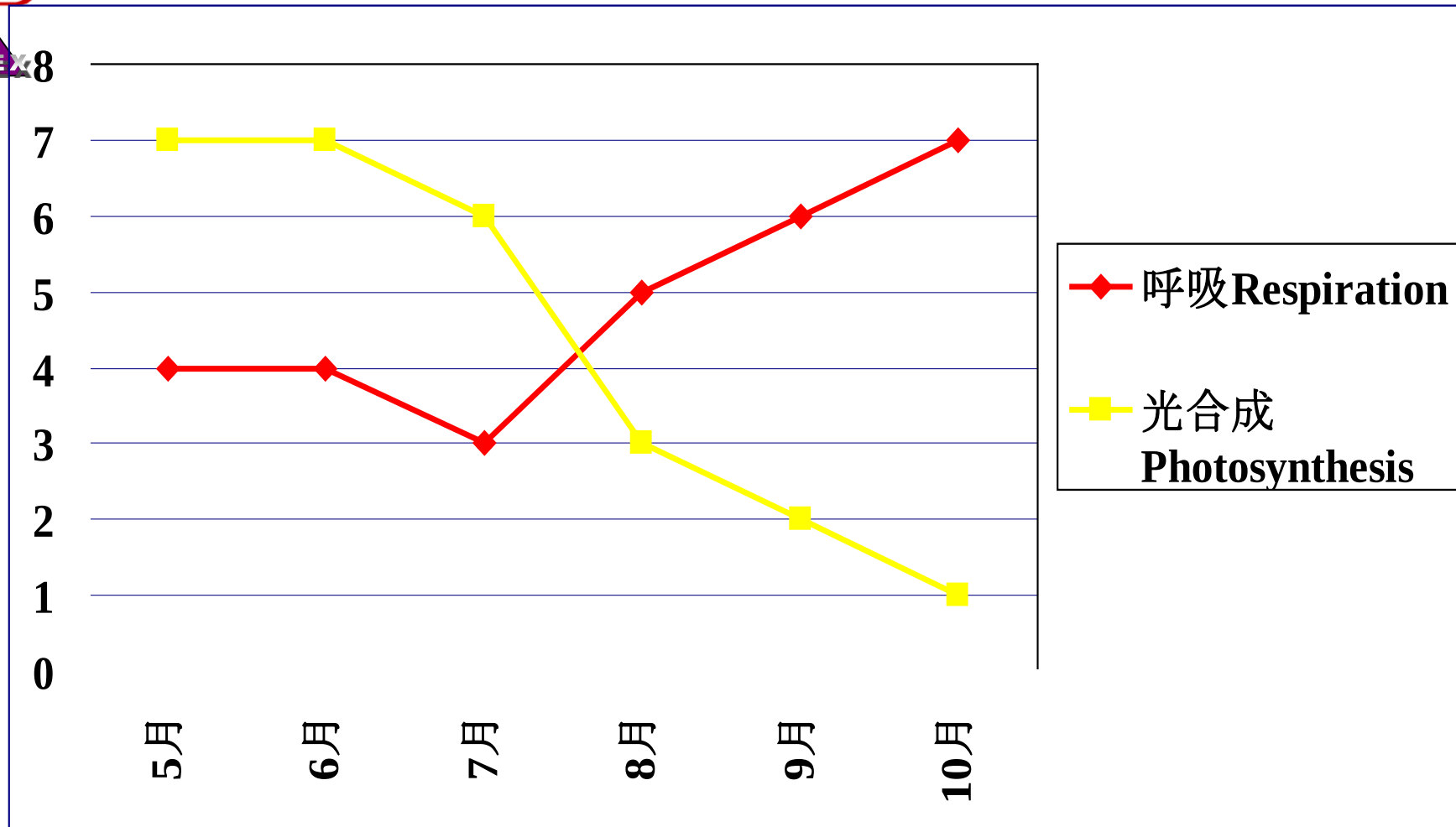
Topgrowth



根部 Roots

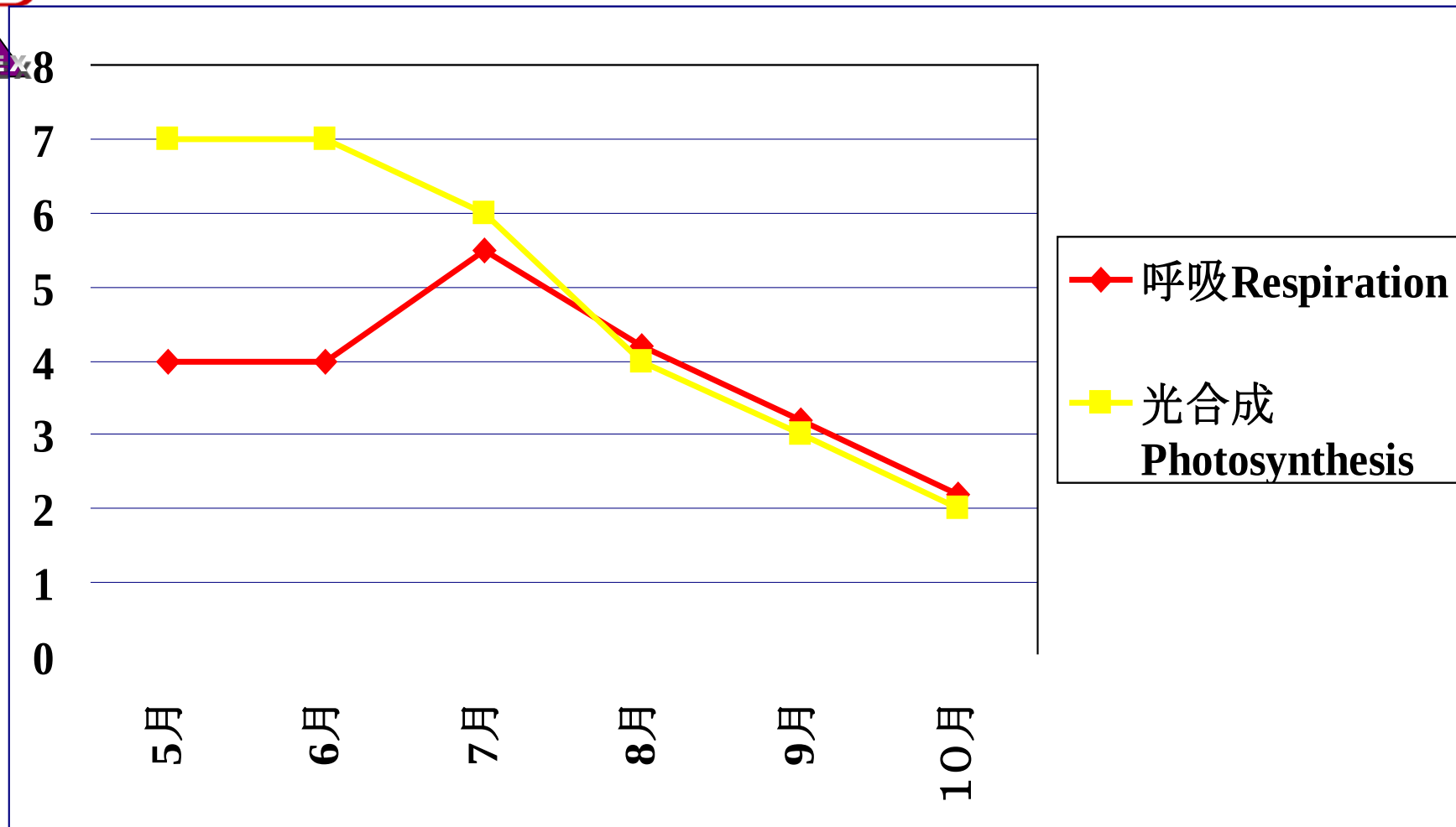
## 芝生の根部と地上部の成長の季節変化

Seasonal patterns of root and shoot growth of turfgrass



## 刈高3.2mmの芝の7月と8月の呼吸が光合成を超える

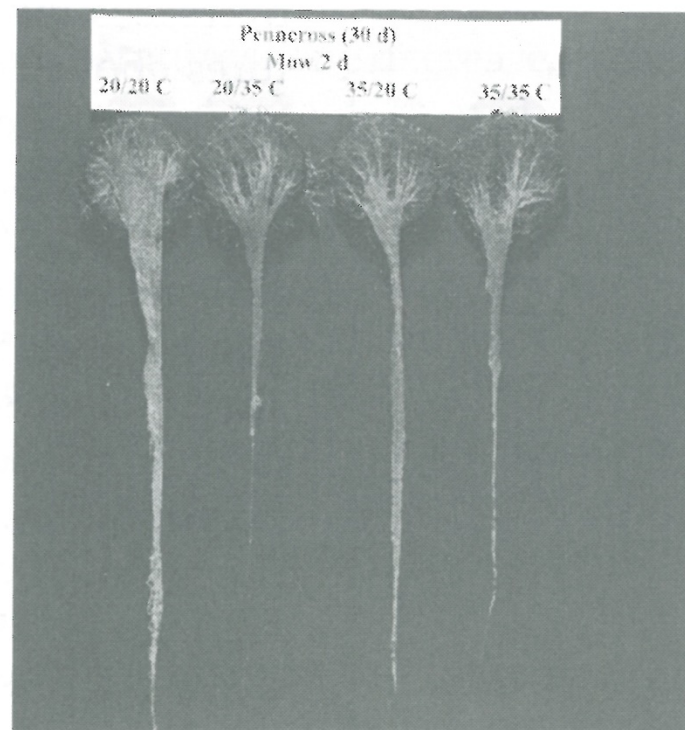
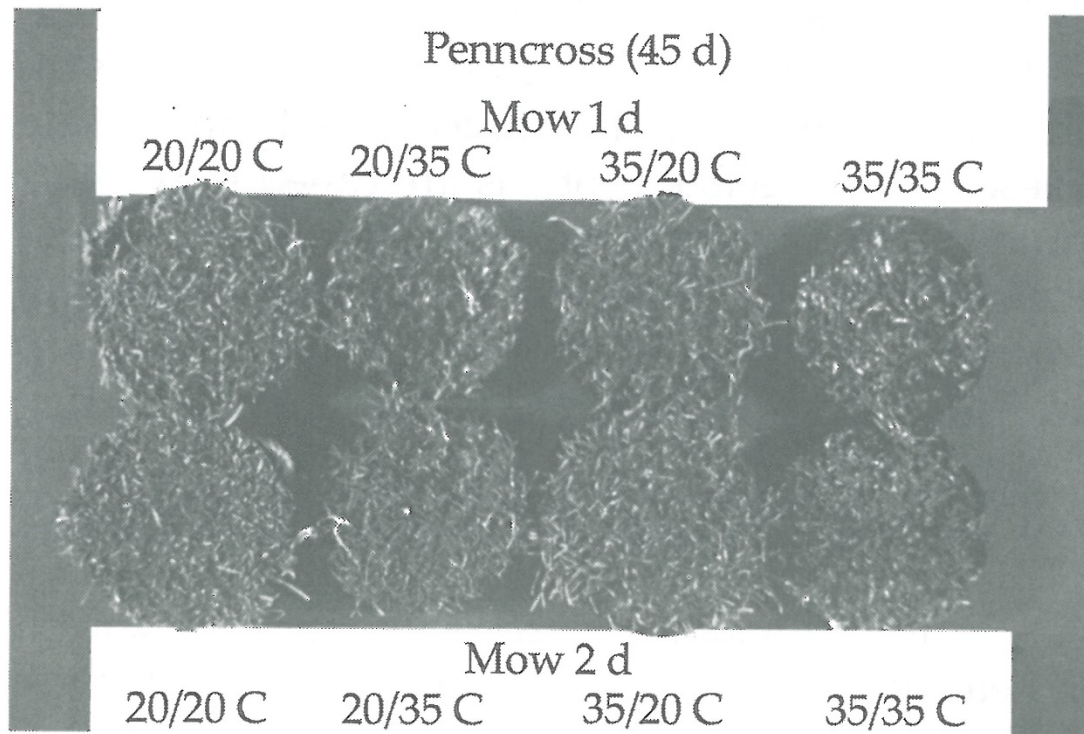
In July and August respiration exceeds photosynthesis in turf grass mowed at 1/8 inch



## 刈高4mmの芝の光合成と呼吸

Photosynthesis and respiration in turf grass mowed at 5/32 inch

葉からの蒸散作用で  
葉の温度を3~10℃  
下げることができる



Figures 4-10 and 4-11



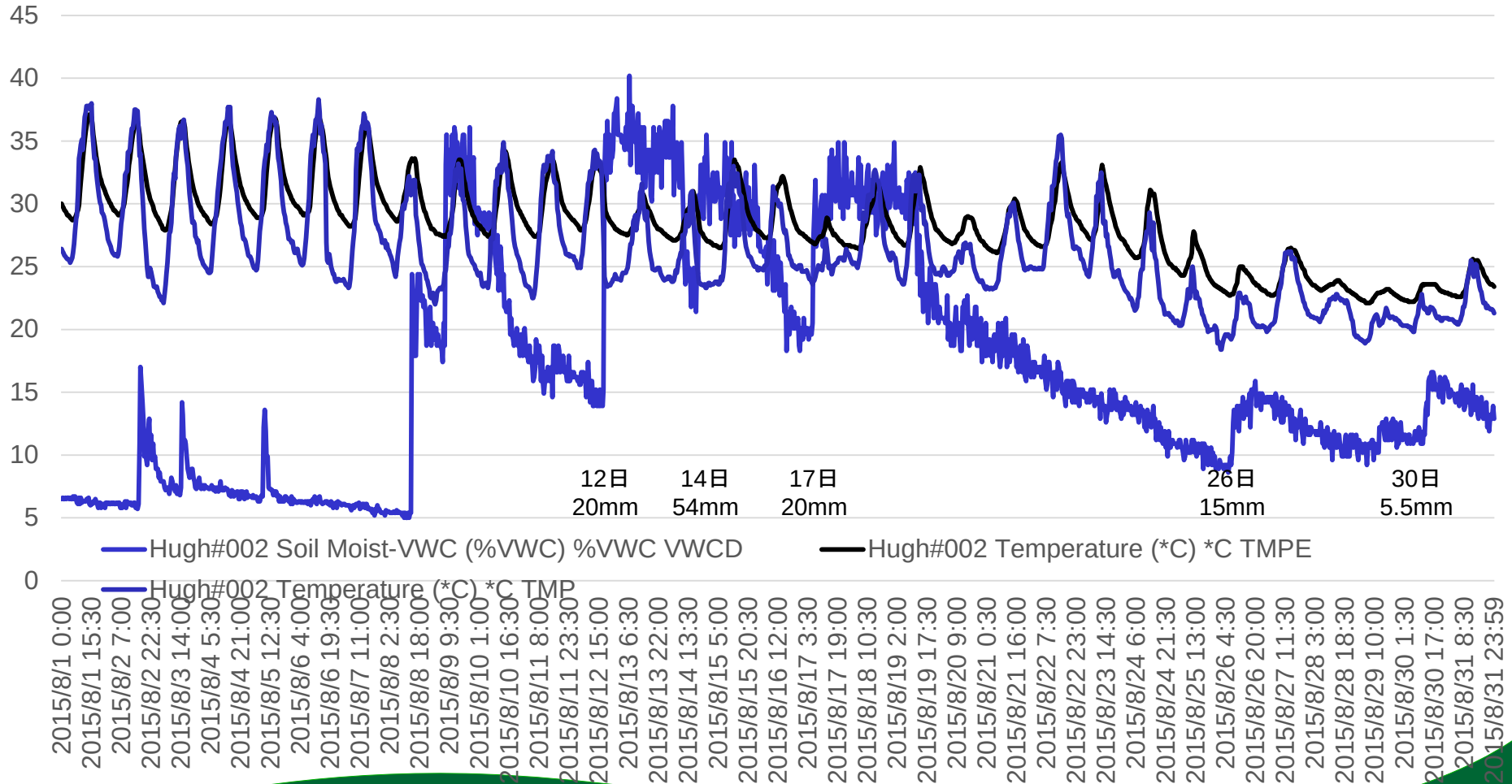
# 芝生の成長と温度

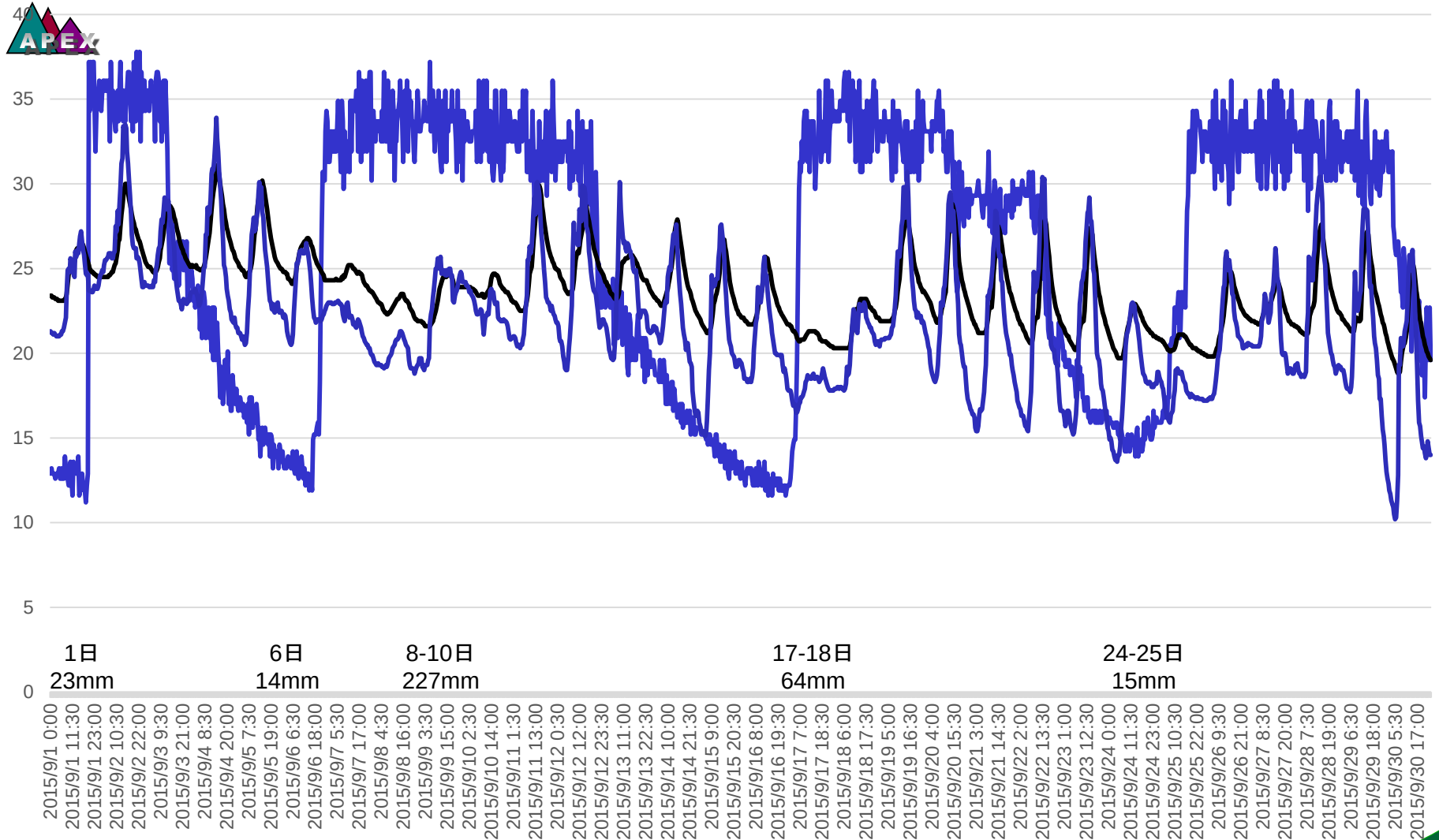
土壌10cm

| (°C)   | 寒地型   |         | 暖地型   |        |
|--------|-------|---------|-------|--------|
| 芝の状態   | 気温    | 土壌温度    | 気温    | 土壌温度   |
| 高温枯死   | 55    |         | >60   |        |
| 茎葉生育限界 | 32    |         | 49    |        |
| 根部成長限界 |       | 21-24   |       |        |
| 植栽的期   | 24-27 | 15.6-21 | 27-32 | 21-27  |
| 茎葉成長的期 | 15-25 |         | 27-38 |        |
| 根部成長的期 |       | 10-18   |       | 24-29  |
| 最低茎葉成長 | 4.4   |         | 13    |        |
| 最低根部成長 |       | 0.6     |       | 1.7-10 |



2015年8月





— Hugh#002 Soil Moist-VWC (%VWC) %VWC VWCD — Hugh#002 Temperature (°C) \*C TMPE — Hugh#002 Temperature (°C) \*C TMP



# PROFESSIONAL PRODUCTS

16777 HOWLAND ROAD, P.O. BOX 198, LATHROP, CA 95330 • (209) 858-2511 • FAX (209) 858-2519

REPORT NUMBER: 18-106-098

GROWER:

SEND TO: HUGH ENTERPRISE LTD  
5-28 SHINOAWAMACHI  
SHINJU-KU TOKYO

SUBMITTED BY:

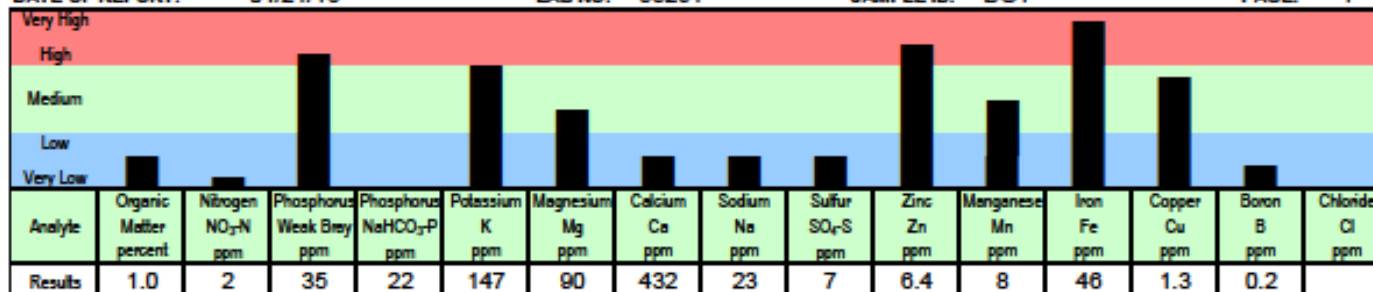
## Graphical Soil Analysis Report

DATE OF REPORT: 04/21/18

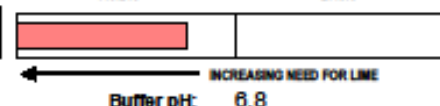
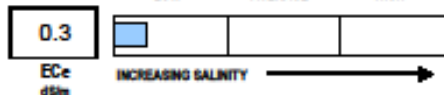
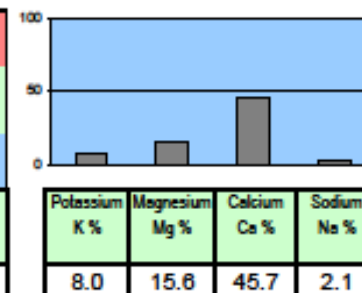
LAB NO: 55291

SAMPLE ID: BG1

PAGE: 1



## Percent Cation Saturation (computed)



NaHCO<sub>3</sub>-P unreliable at this soil pH

## Soil Fertility Guidelines

CROP: CREEPING BENT

RATE:

NOTES:

| Dolomite (70 score) | Lime (70 score) | Gypsum | Elemental Sulfur | Nitrogen N | Phosphate P <sub>2</sub> O <sub>5</sub> | Potash K <sub>2</sub> O | Magnesium Mg | Sulfur SO <sub>4</sub> -S | Zinc Zn | Manganese Mn | Iron Fe | Copper Cu | Boron B |  |
|---------------------|-----------------|--------|------------------|------------|-----------------------------------------|-------------------------|--------------|---------------------------|---------|--------------|---------|-----------|---------|--|
|                     | 10              |        |                  | 2.8        | 1                                       | 1.2                     |              | 0.3                       |         |              |         |           | *       |  |

- C** PLEASE NOTE! These recommendations are expressed in kg/100 sq meters and not lb/1,000 sq ft. Please contact us with any questions. Thank you.
- O**
- M** ORGANIC MATTER maintained above 1.0% will provide an improved environment with a more sustained release of nutrients. However, exceeding 3.0-4.0% on greens may actually impair turf health.
- M**
- E** THATCH CONTROL is necessary to discourage insect and disease problems, and avoid poor water penetration.
- N** Light vertical cutting plus topdressings (and liming if low pH) will aid decomposition.
- T** LIME ON TURF: Avoid exceeding 25 kg/100 sq m at any one time on established turf, as higher rates may cake on the thatch. Consider pelletized products for ease of application.
- S**

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*Phoebe Gordon*

Phoebe Gordon, PhD

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# 水管理

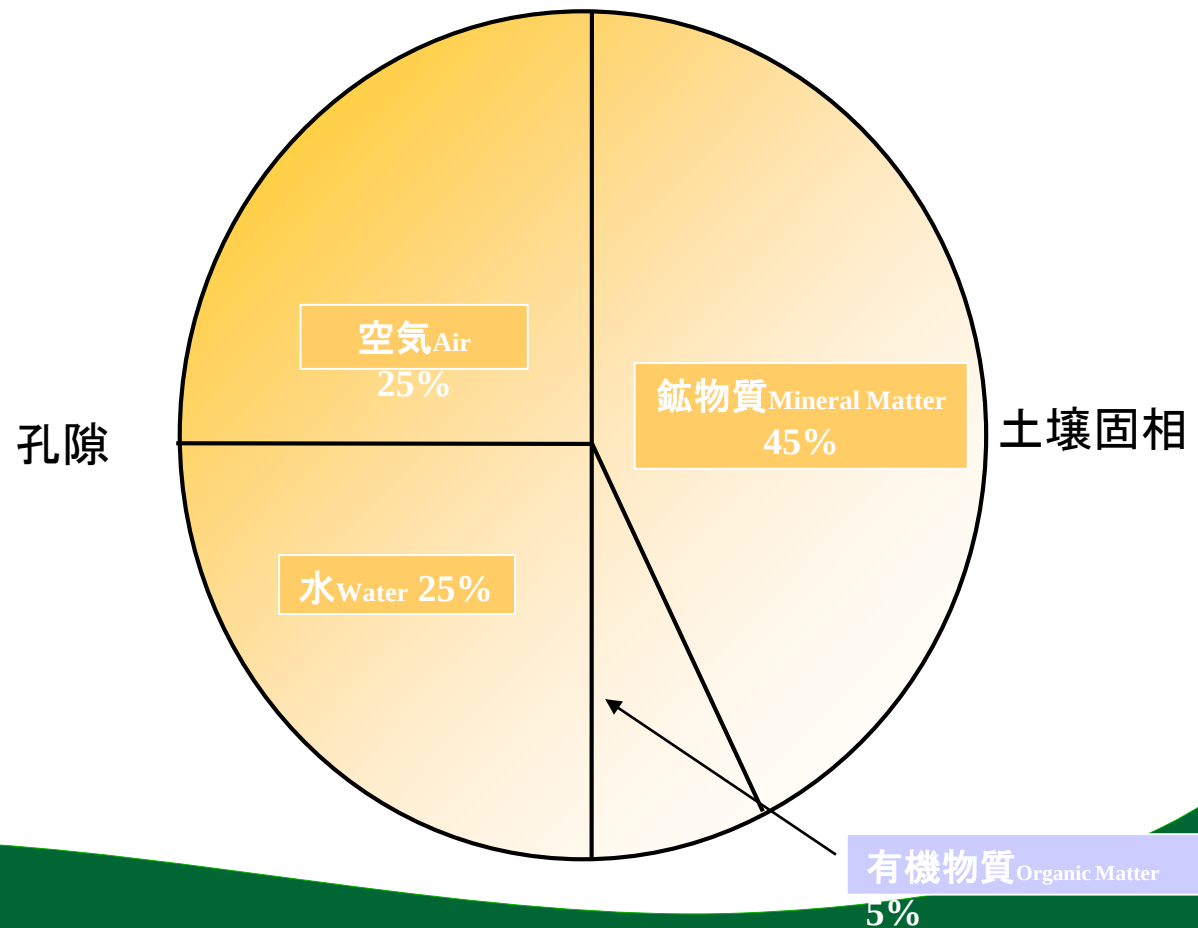
- 浸透率（Infiltration Rate）
  - 土壌粒子
  - 雨または散水時の土壌の水分量

# 土壌水分量による浸透率

| 土壌の種類   | 単位   | 永久しおれ点 | 芝の障害目視 | 土壌保水量 | 土壌飽和 |
|---------|------|--------|--------|-------|------|
| サンディローム | mm/時 | 122    | 114    | 107   | 60   |
| ローム     | mm/時 | 35     | 33     | 31    | 20   |
| シルト/ローム | mm/時 | 17     | 15     | 12.5  | 5    |
| シルト/粘土  | mm/時 | 7      | 5.3    | 3.6   | 1    |

# 土壌の構成物質（三相組成）

- 無機物
- 有機物
- 空気
- 水



## 根の成長・維持に必要なもの

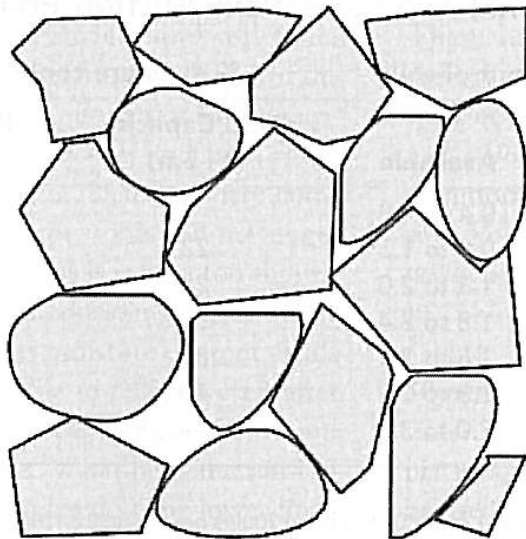
- 養分
- 水
- 空気

土壌水分量の管理は、土壌中の空気の管理である



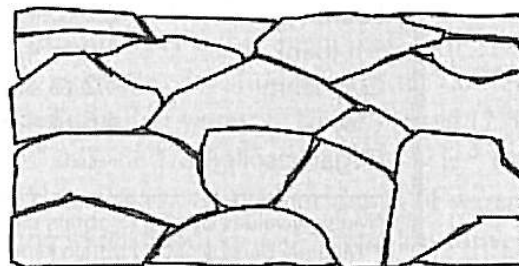
# 仮比重

## Bulk Density



Bulk Density =  $1.0 \text{ g/cm}^3$

## Compaction



Bulk Density =  $1.4 \text{ g/cm}^3$

# 仮比重

- 孔隙率を求める
- 砂の比重 =  $2.6 \sim 2.75 \text{g/cc}$
- 有機物の比重 =  $0.2 \sim 1.0 \text{g/cc}$
- 仮比重 = 乾燥土壌 (g)  $\div$  土壌総容積 (cc)
- クレイ・クレイローム・シルト =  $1.0 \sim 1.6 \text{g/cc}$
- 砂・サンディローム =  $1.2 \sim 1.8 \text{g/cc}$

# 仮比重・孔隙率

- サンドグリーンの場合
- 仮比重は1.25～1.55g/cc
- 理想は1.40g/cc
- 孔隙率(%) = (仮比重/粒子比重) × 100

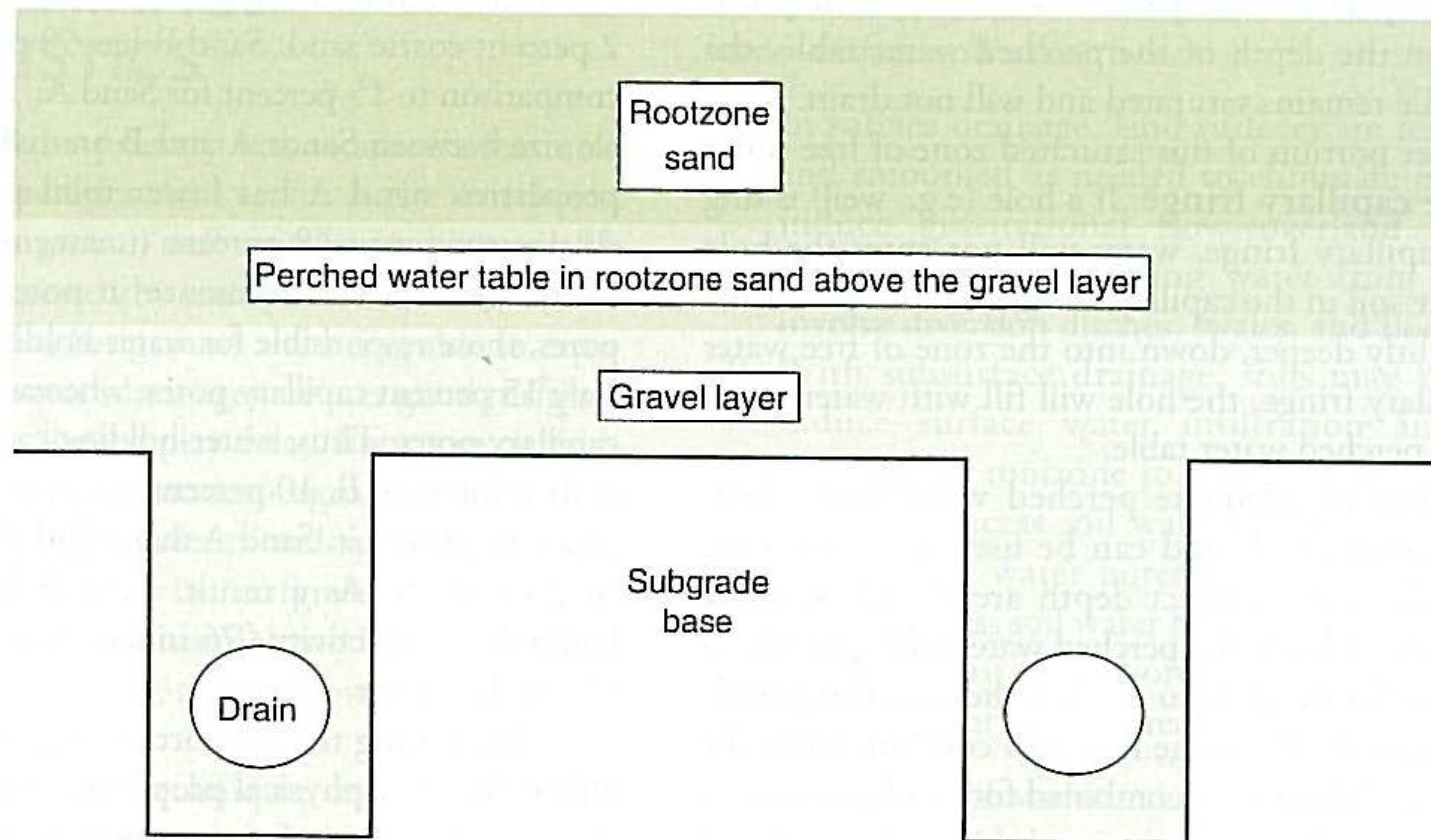
# グリーンの砂

|     | 粒子サイズ      | USGA方式  |     | カルフォルニア方式 |
|-----|------------|---------|-----|-----------|
|     | mm         | %       |     |           |
| 粘土  | <0.002     | <3      | <10 | 0-8       |
| シルト | 0.002-0.05 | <5      |     |           |
| 微細砂 | 0.05-0.15  | <5      |     |           |
| 細砂  | 0.15-0.25  | <20     | <60 | 82-100    |
| 中砂  | 0.25-0.5   | <35(75) |     |           |
| 荒砂  | 0.5-1.0    | <45     |     |           |
| 大荒砂 | 1.0-2.0    | <7      | <10 | 0-10      |
| 砂利  | >2         | <3      |     |           |

# USGAレートゾーンミックス

| 粒              |                            | 推奨                                           |
|----------------|----------------------------|----------------------------------------------|
| 名前             | 直径                         | (重量で)                                        |
| 細かい砂利<br>大変粗い砂 | 2.0-3.4mm<br>1.0-2.0mm     | このレンジの粒子は3%の細かい砂利（できれば0%）を含み、全体で10%を超えてはならない |
| 粗い砂            | 0.5-1.0mm                  | 最低60%このレンジが含まれていなければならない                     |
| 中庸砂<br>細かい砂    | 0.25-0.50mm<br>0.15-0.25mm | 最低20%はこのレンジが含まれていなければならない                    |
| 大変細かい砂         | 0.05-0.15mm                | 5%以下                                         |
| シルト            | 0.002-0.05mm               | 5%以下                                         |
| 粘土             | 0.002mm以下                  | 3%以下                                         |
| 合計の細粒          | 大変細かい砂+シルト+粘土              | 10%以下                                        |

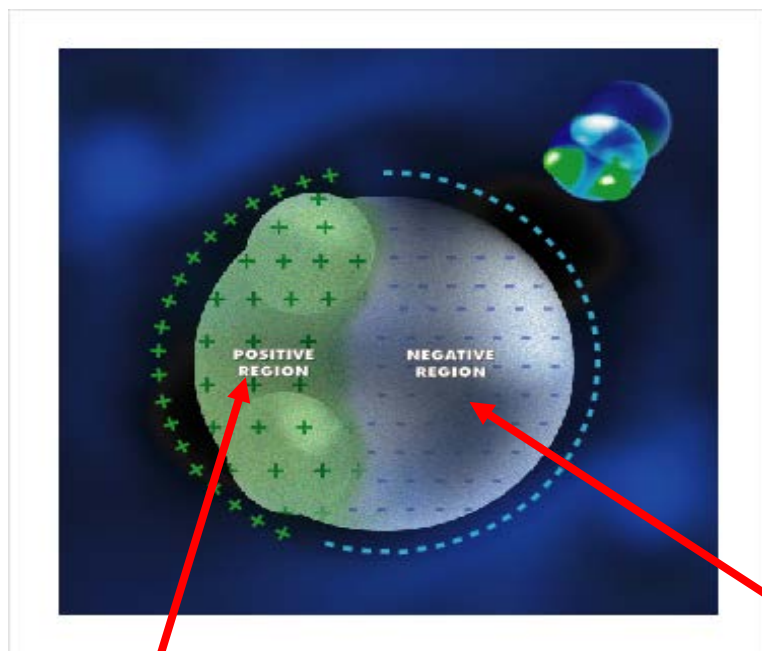
# グリーンの構造



# 水分子 THE WATER MOLECULE

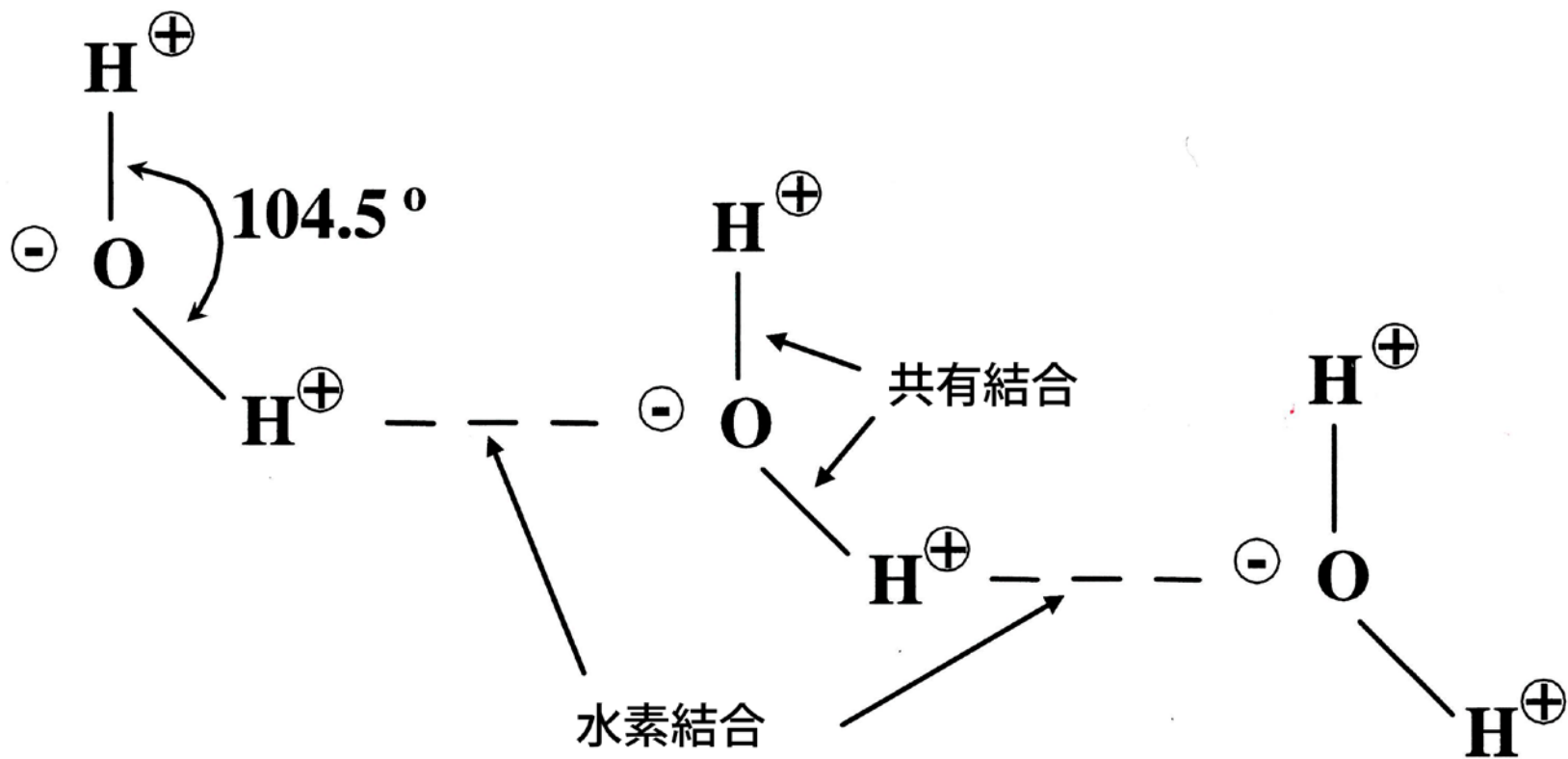
水分子は  
双極

THE WATER MOLECULE IS  
DIPOLAR

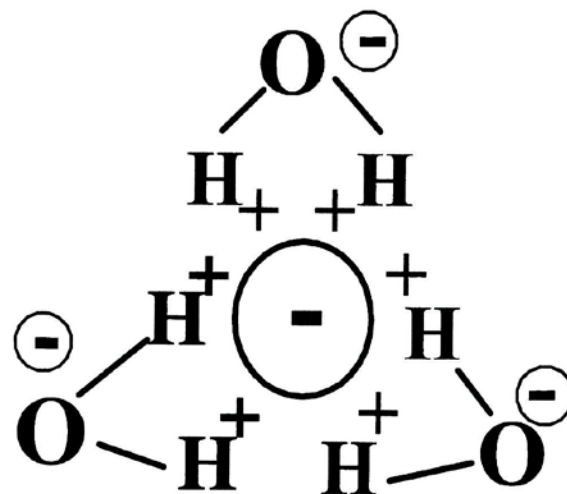
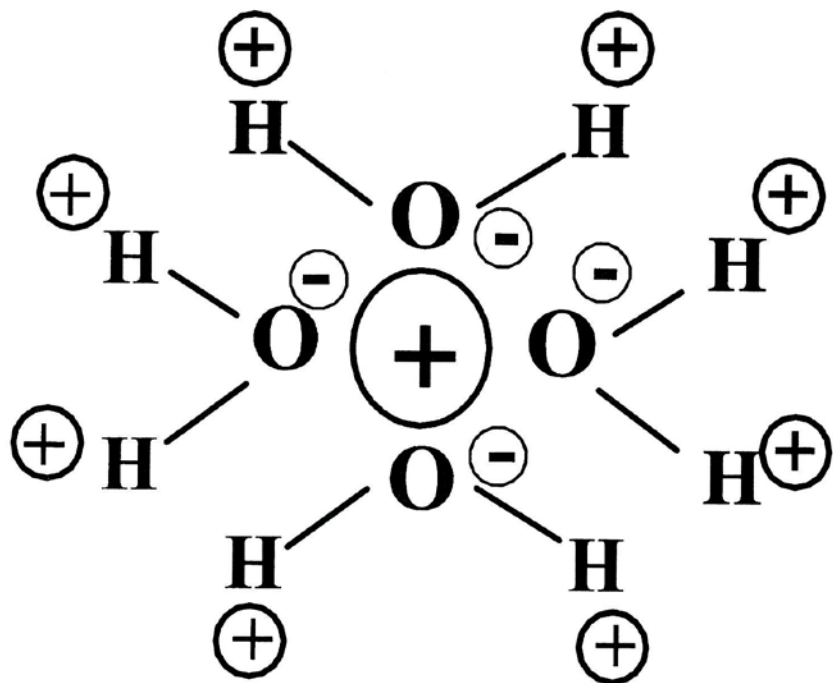


水素側～プラス極  
The Hydrogen End – Positive Potential

酸素側～マイナス極  
The Oxygen end – Negative Potential







# 利用可能な水

Water Availability

張力(バール) Tension (bar)

カラカラの乾燥 Oven Dry (-10,000)

利用不可 NOT AVAILABLE

弱る部分 Wilting Point (-15)

利用不可 NOT AVAILABLE

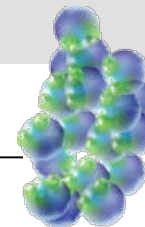
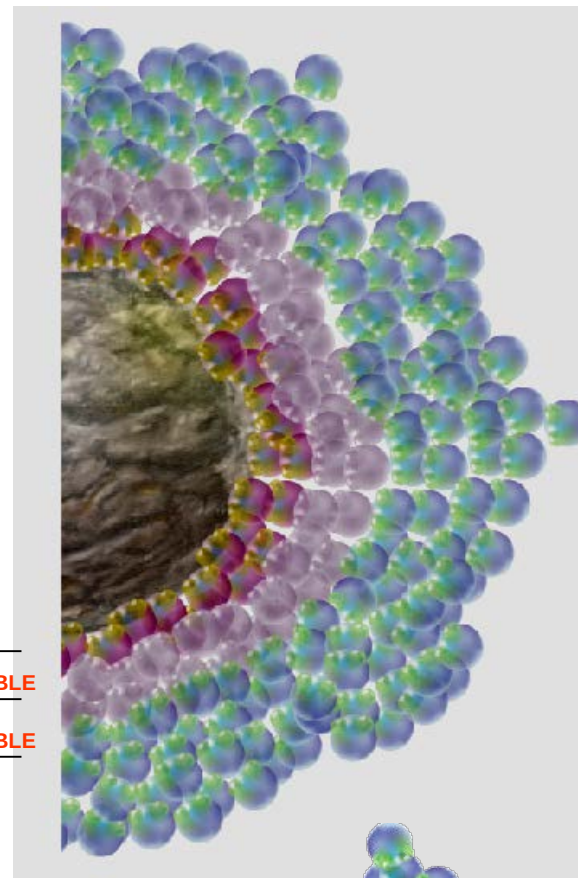
利用可能水

AVAILABLE WATER

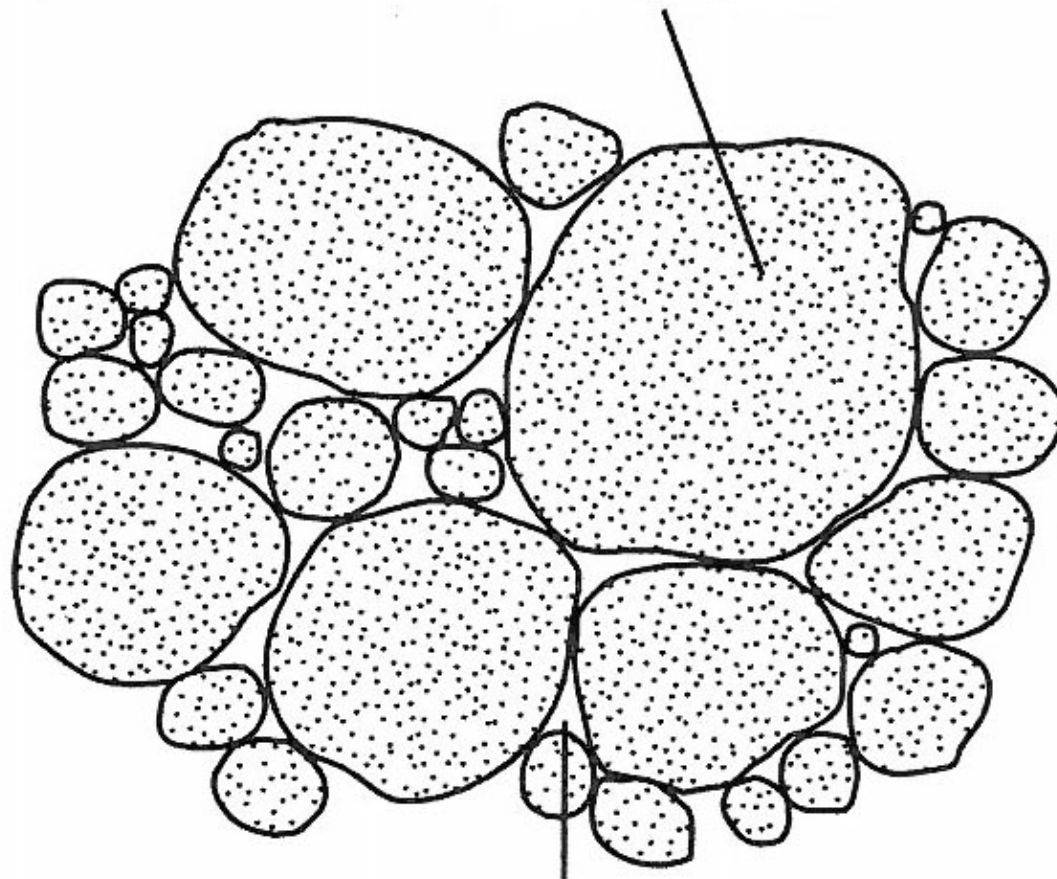
湿りやすい共同因子 Hygroscopic Coefficient (-31)  
抱え込む領域 Field Capacity (-0.3)

利用不可 NOT AVAILABLE

重力作用水 Gravitational Water (>0.3)

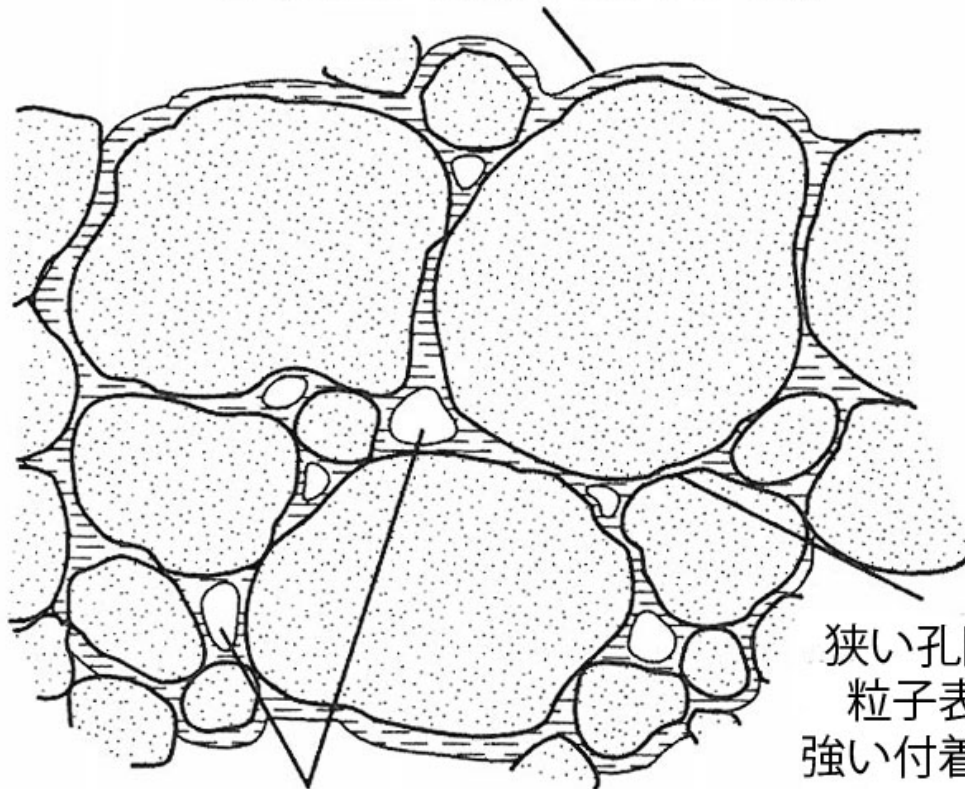


土壤粒子



土壤孔隙

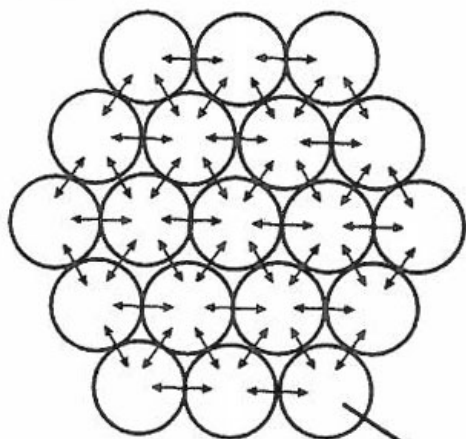
重力に反して表面張力の力で  
土壌粒子の表面に付着する水



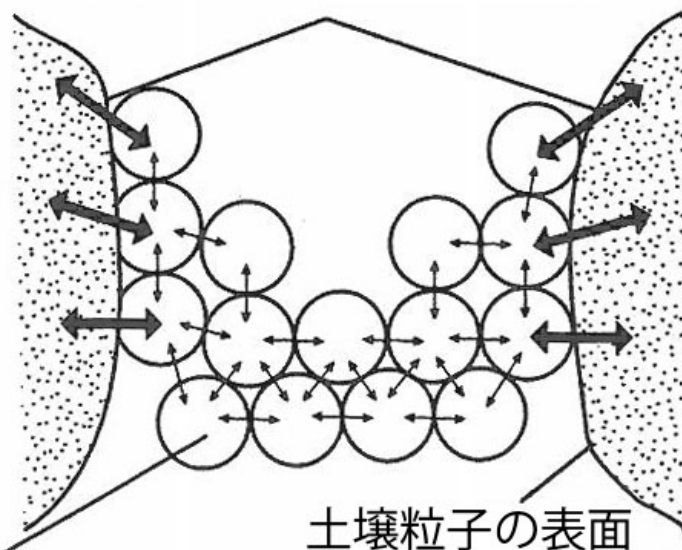
狭い孔隙は水と  
粒子表面との  
強い付着が起こる

巨大孔隙中の空気

空気中の水分子  
お互いの凝集力で集まる

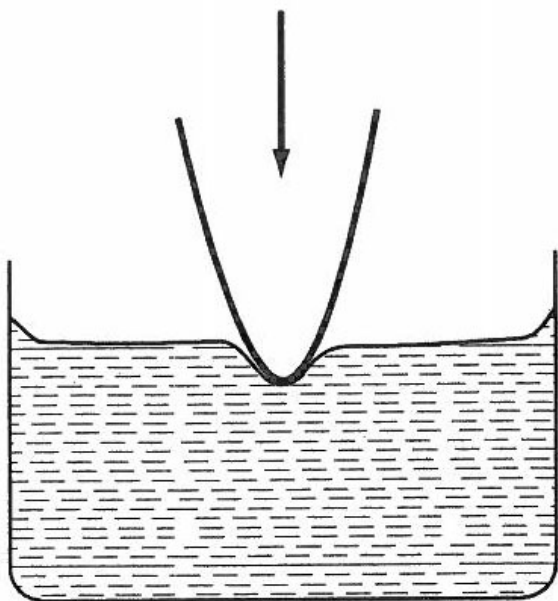


水分子が土壌粒子表面と  
界面力で強固に引き付け合う

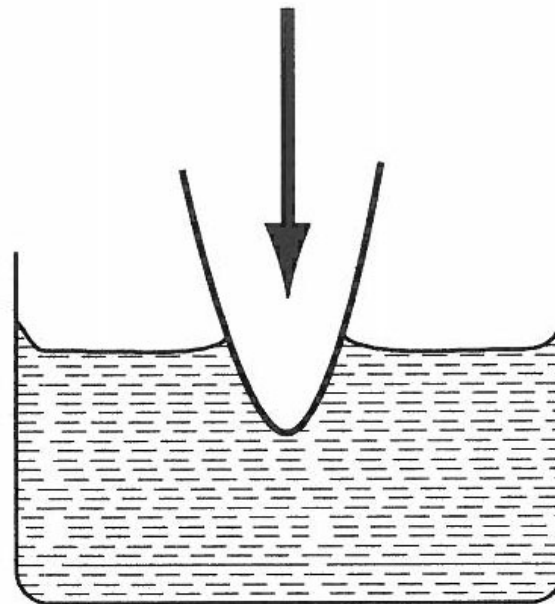


水分子同士の凝集力で引き付け合う



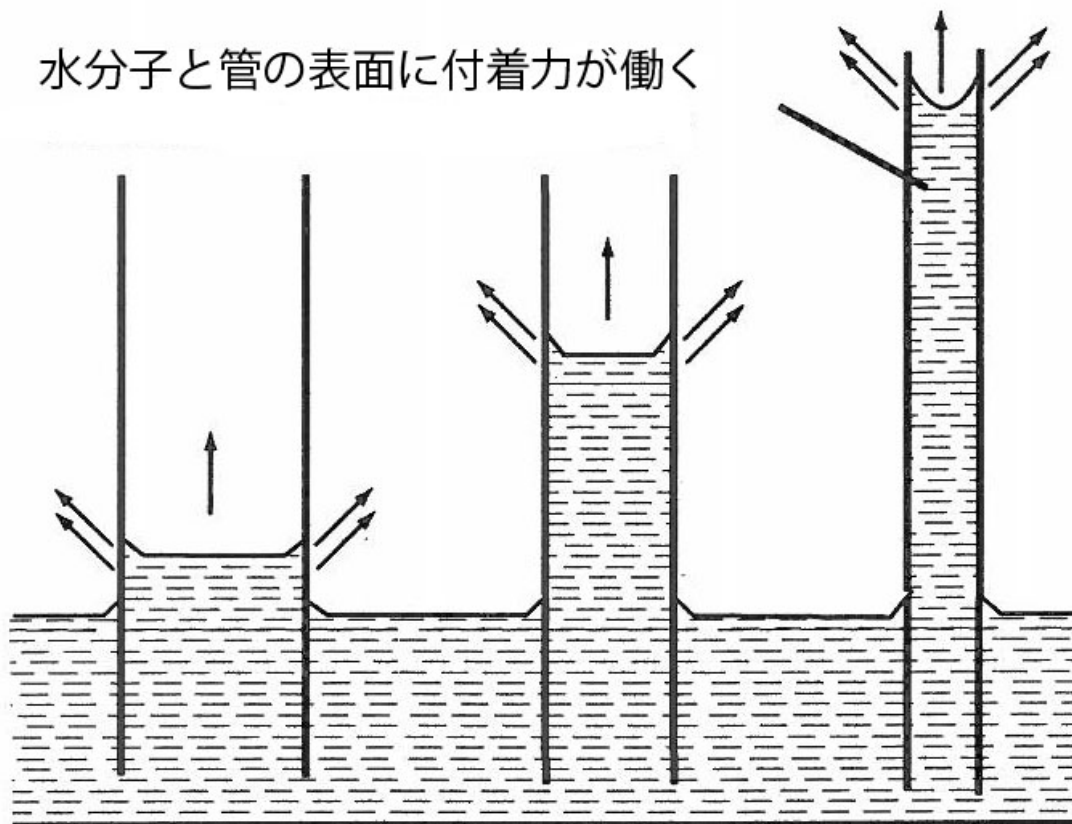


緩やかな力で  
表面張力を押さえる



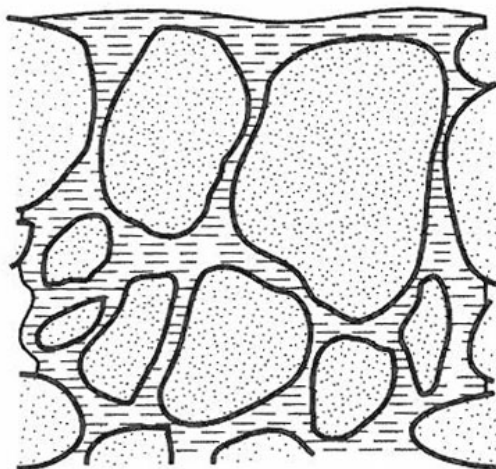
強い力で表面張力を  
破る

水分子と管の表面に付着力が働く

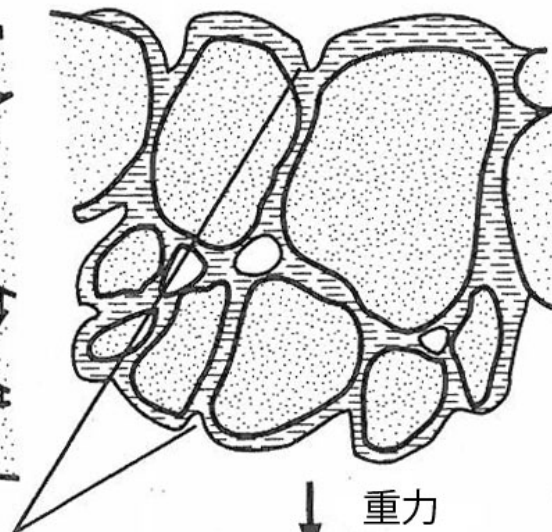


付着力によって重力に反して上に向かって水が移動する  
毛細管現象

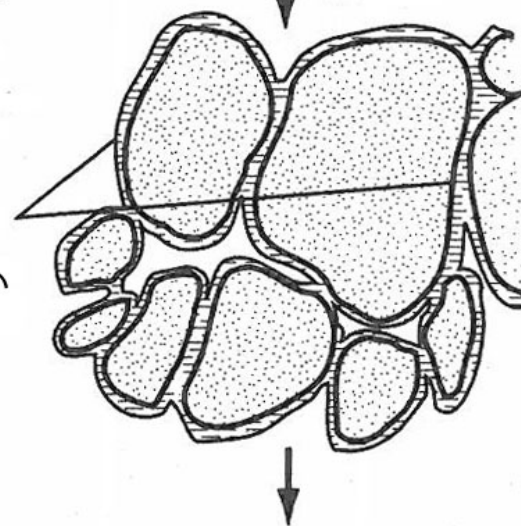
土壌粒子間に水が飽和した状態



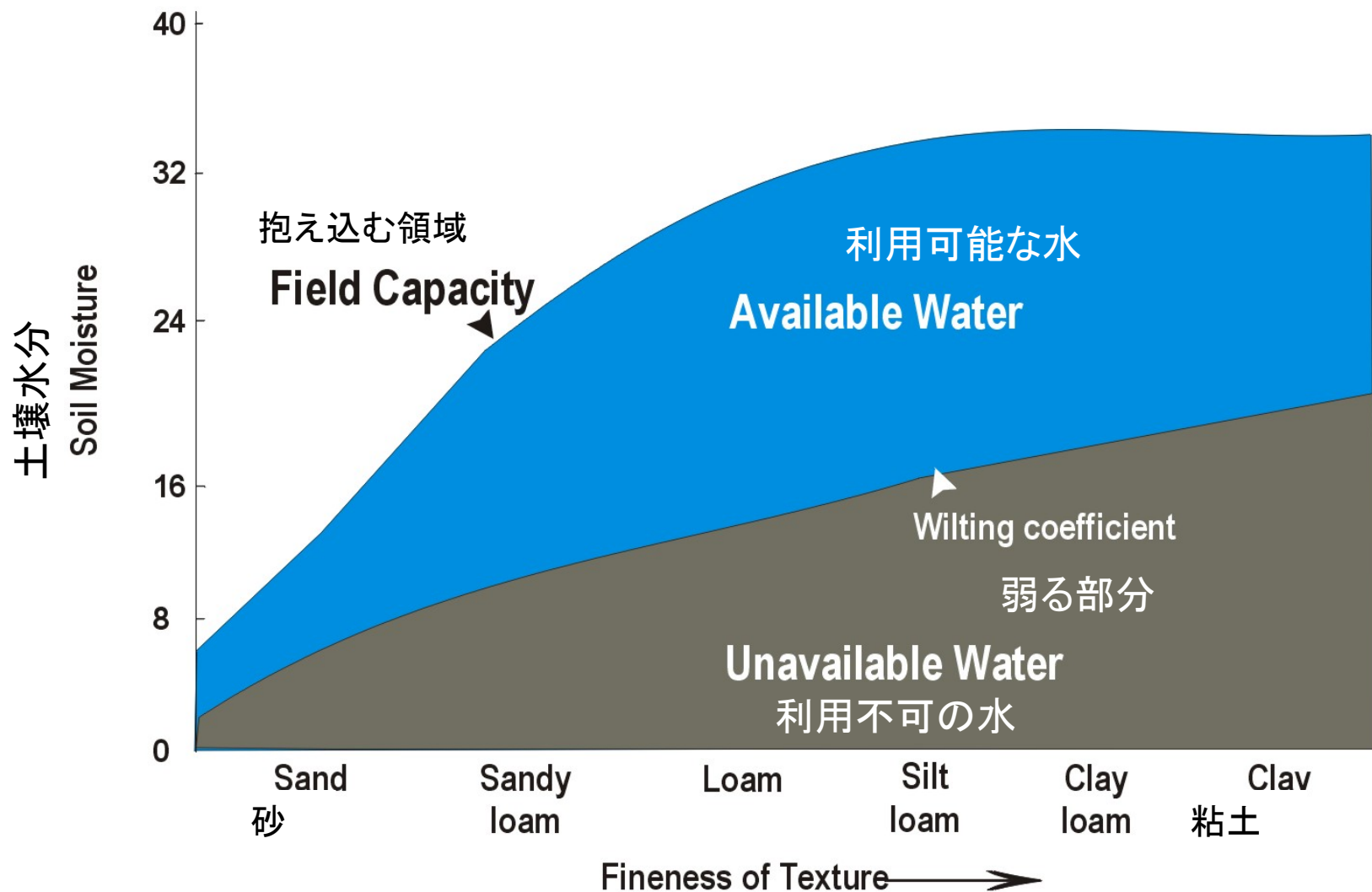
徐々に重力で水が下に落ちて  
表面張力により粒子表面に水が残る



水分子と粒子表面との  
間に強い付着力が働き  
これ以上重力によって  
引き離すことができない







きめ細かくなる

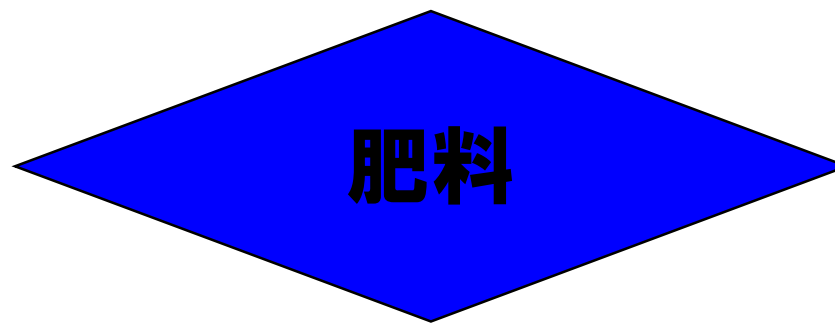
Simplot

# CEC(陽イオン交換容量)

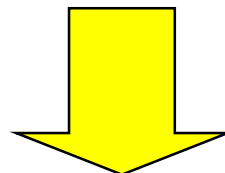
| CEC     | 土壌の種類 |
|---------|-------|
| 0 - 8   | 砂     |
| 8 - 12  | 砂壌土   |
| 13 - 20 | シルト壌土 |
| 21 - 28 | 壌土    |
| 29 - 40 | 粘土壌土  |
| > 40    | 粘土    |

# 養分管理

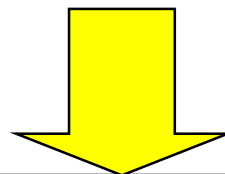
- 与えた養分量（施肥量）
- 芝生が吸収した養分量（吸収量）
- 土壌が水で飽和すると脱窒が加速する
- C E Cの低いサンドグリーンでは降雨・散水で窒素が流亡する
- 夏場のストレスにKが有効



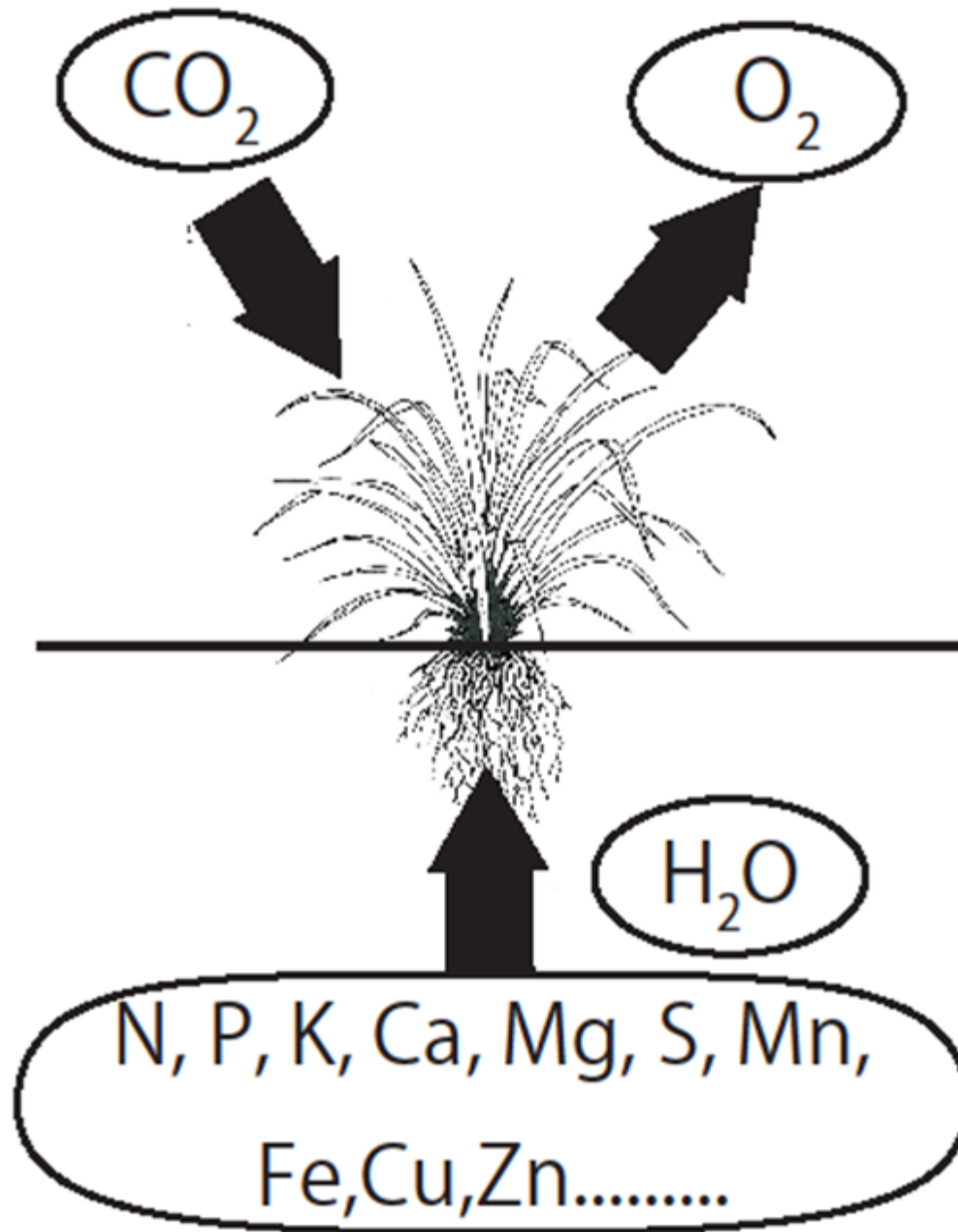
肥料の中身は？



土壌の物理性  
化学性・微生物層は？  
土壌温度は？



根の張り  
芝種  
植物の健康状態は？  
気象条件は？



# 陽イオンと陰イオン

| 養分     | 元素記号 | 通常植物によって<br>吸収されるイオン形<br>態                      |
|--------|------|-------------------------------------------------|
| 窒素     | N    | $\text{NO}_3^-$ , $\text{NH}_4^+$               |
| リン     | P    | $\text{H}_2\text{PO}_4^-$ , $\text{HPO}_4^{2-}$ |
| カリウム   | K    | $\text{K}^+$                                    |
| カルシウム  | Ca   | $\text{Ca}^{2+}$                                |
| マグネシウム | Mg   | $\text{Mg}^{2+}$                                |
| 硫黄     | S    | $\text{SO}_4^{2-}$                              |

# 窒素必要量

Nitrogen Fertility Response Range

成長月1ヶ月

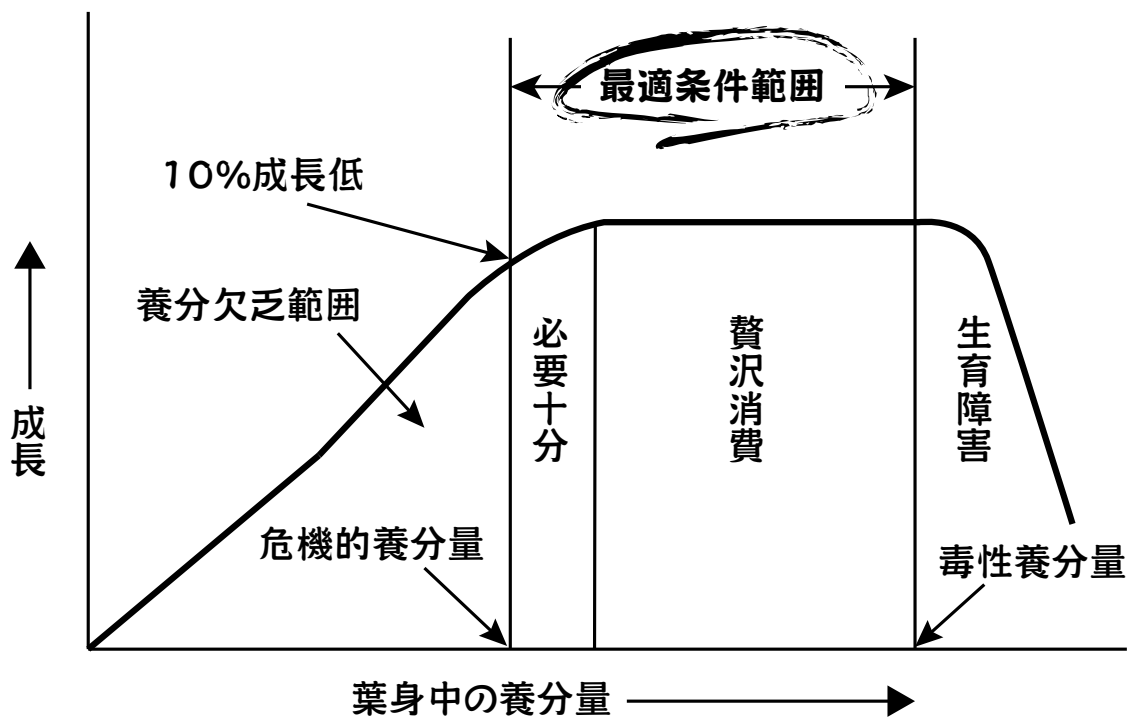
| 窒素必要レベル | $g/m^2$   | 芝種                                       |
|---------|-----------|------------------------------------------|
| 大変低い    | 0.0 – 1.8 | バッファローグラス<br>バヒアグラス<br>センチピードグラス         |
| 低い      | 1-3       | チューイングフェスク<br>レッドフェスク                    |
| 中程度     | 1.8- 4.5  | 日本芝<br>ペレニアルライグラス<br>トールフェスク             |
| 高い      | 2.5-6.7   | ケンタッキーブルーグラス<br>クリーピングベントグラス<br>バミューダグラス |

## 植物体内の元素の量

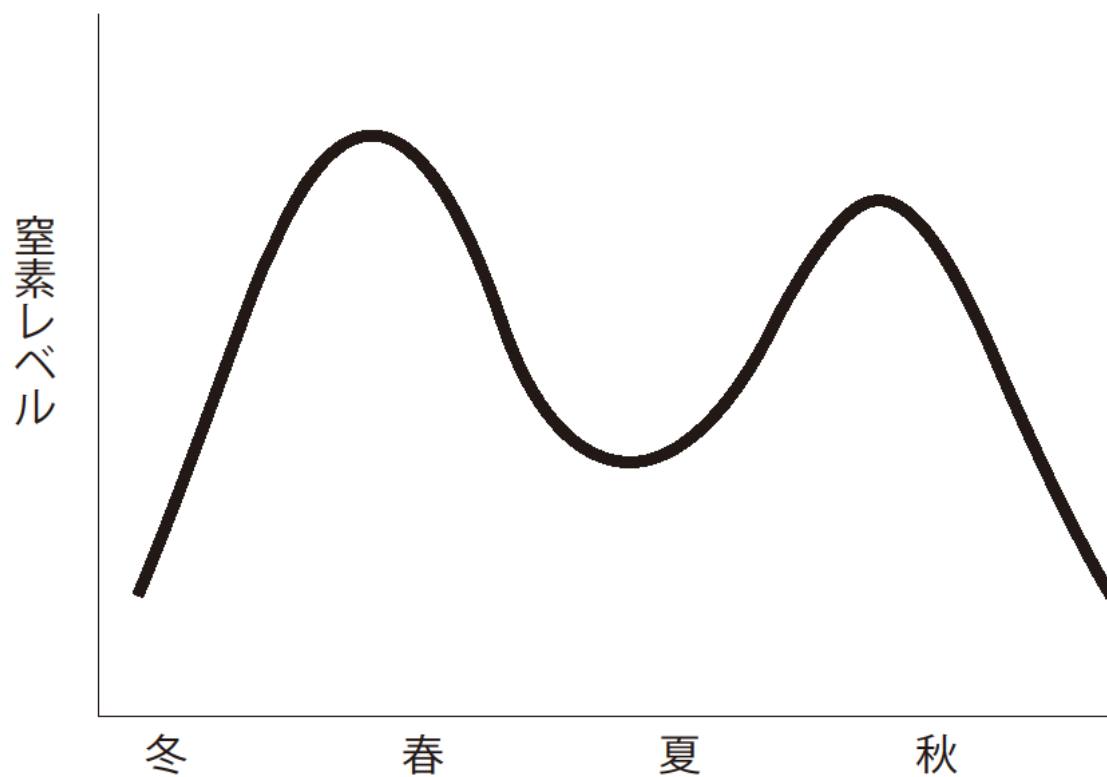
| 養分 |        | 単位  | 乾燥植物体含有量  | 葉身中養分の十分量レベル |            |           |
|----|--------|-----|-----------|--------------|------------|-----------|
|    |        |     |           | クリーピングベントグラス | ペレニアルライグラス | 芝生一般      |
| C  | 炭素     | %   | 45        |              |            |           |
| H  | 水素     | %   | 6         |              |            |           |
| O  | 酸素     | %   | 45        |              |            |           |
| N  | チッソ    | %   | 2.0-6.0   | 4.50-6.00    | 3.34-5.10  | 2.75-3.50 |
| P  | リン     | %   | 0.10-1.0  | 0.30-0.60    | 0.35-0.55  | 0.30-0.55 |
| K  | カリ     | %   | 1.0-3.0   | 2.20-2.60    | 2.00-3.42  | 1.00-2.50 |
| Ca | カルシウム  | %   | 0.30-1.25 | 0.50-0.75    | 0.25-0.51  | 0.50-1.25 |
| Mg | マグネシウム | %   | 0.15-0.50 | 0.25-0.30    | 0.16-0.32  | 0.20-0.60 |
| S  | 硫黄     | %   | 0.15-0.60 | -            | 0.27-0.56  | 0.20-0.45 |
| Fe | 鉄      | ppm | 100-500   | 100-300      | 97-934     | 35-100    |
| Mn | マンガン   | ppm | 20-500    | 50-100       | 30-73      | 25-150    |
| Cu | 銅      | ppm | 10-50     | 8-30         | 6-38       | 5-20      |
| Zn | 亜鉛     | ppm | 20-70     | 25-75        | 14-64      | 20-55     |
| B  | ホウ素    | ppm | 5-50      | 8-20         | 5-17       | 10-60     |
| Mo | モリブデン  | ppm | 1-8       | -            | 0.5-1.00   | -         |



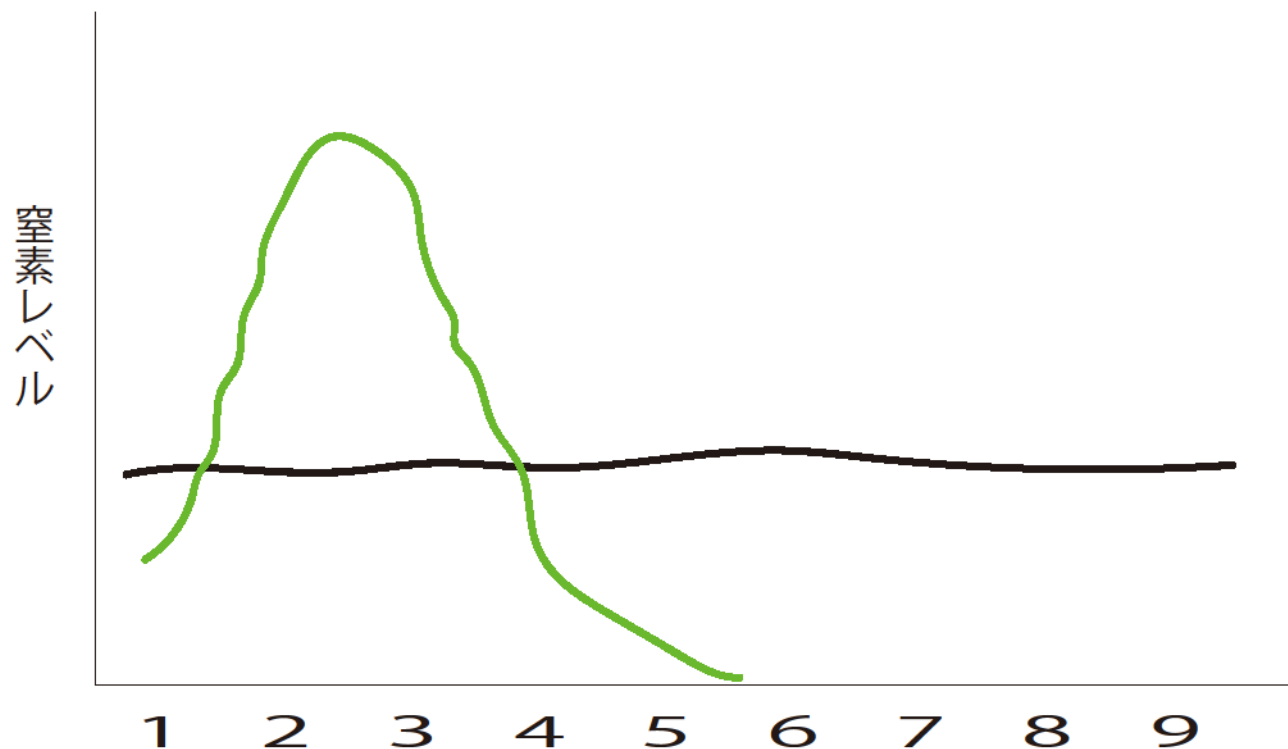
# 葉身中の養分量と成長



# 養分要求量と施肥



# 養分要求量と施肥

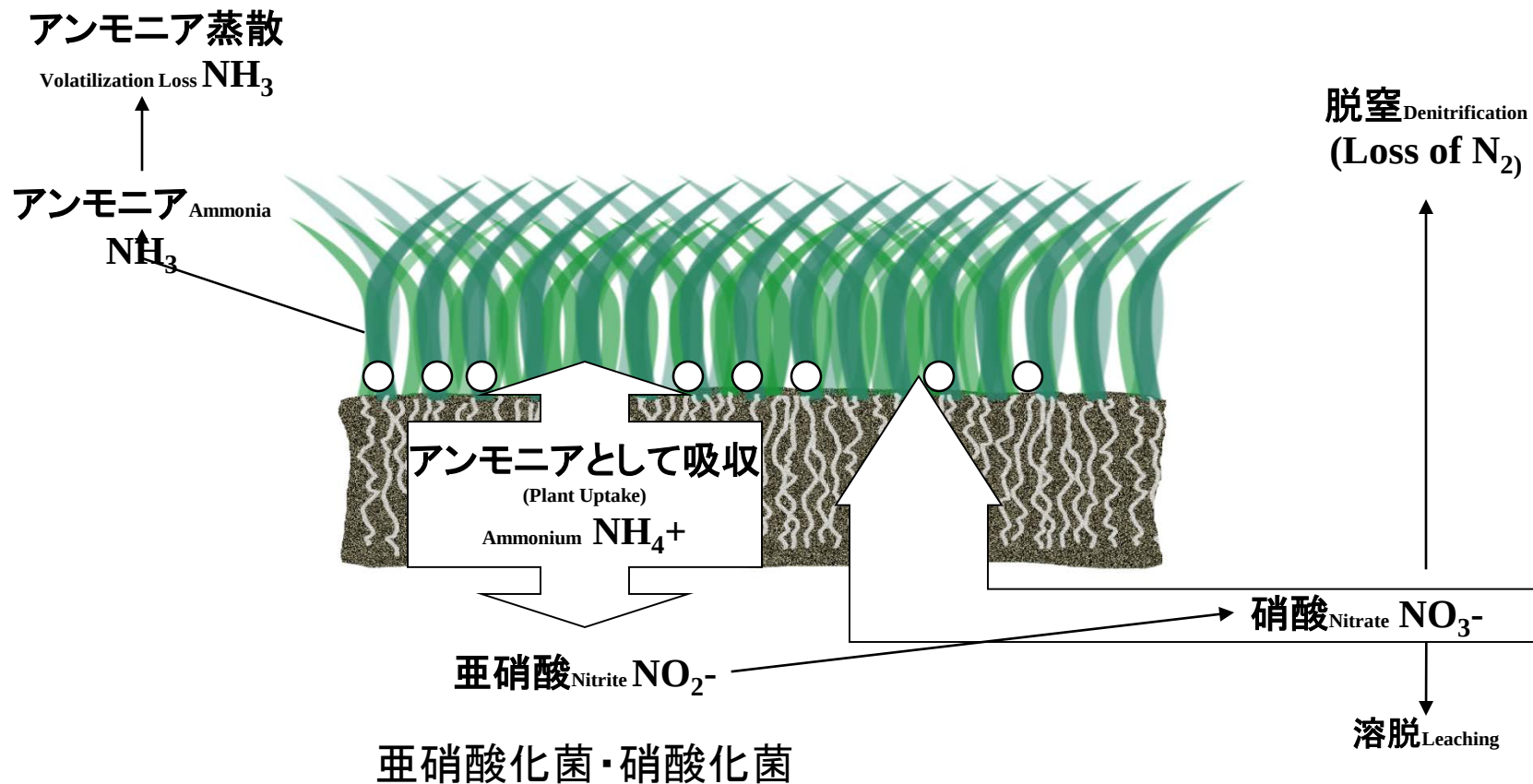


# 葉緑素計

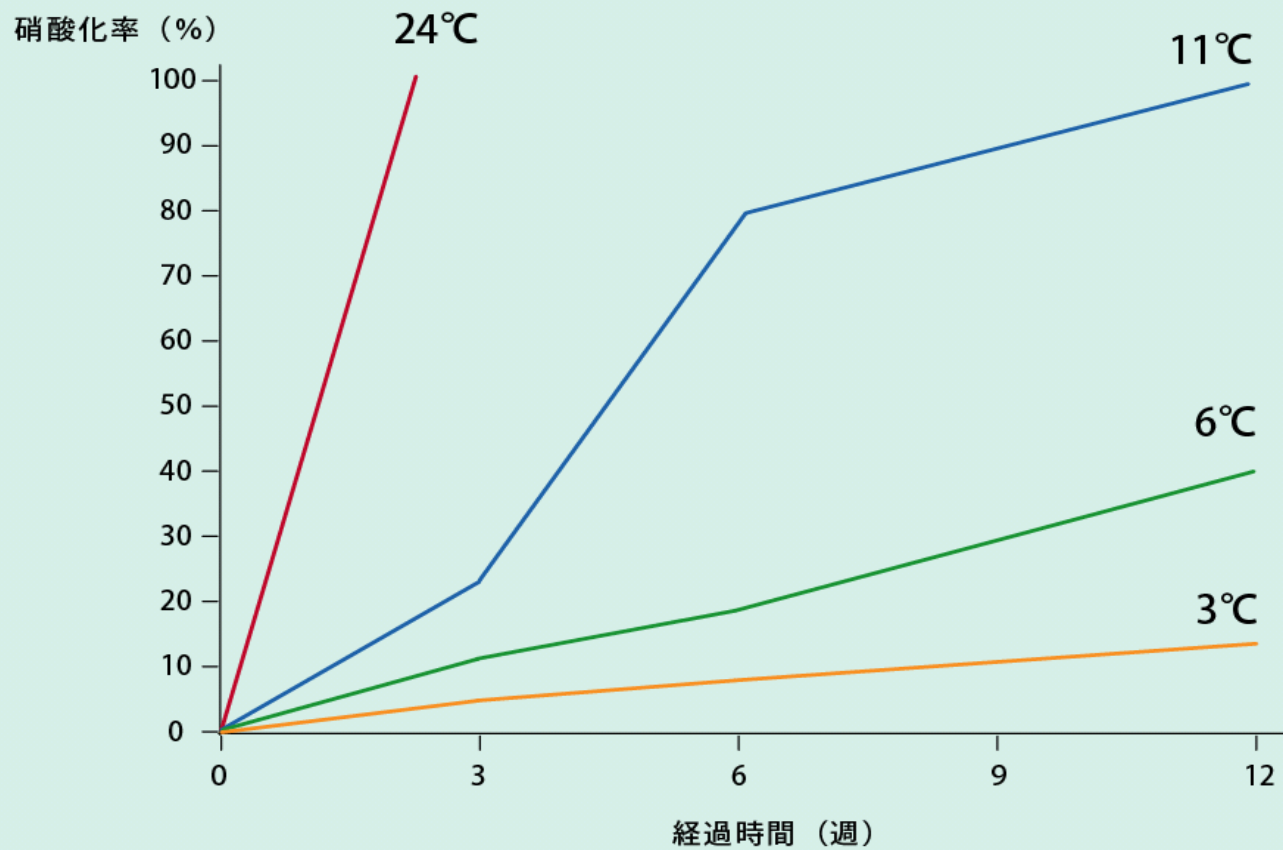


# 窒素固定がどのように働くか

How Does Stabilized Nitrogen Work?



## 土壤温度と硝酸化率



# 土壌温度と土壌微生物の活動

| 土壌温度 (°C) | 相対的活動量 |
|-----------|--------|
| 0         | 4%     |
| 10        | 11%    |
| 12.7      | 17%    |
| 20        | 33%    |
| 30        | 100%   |

# サンドグリーンに有機物は必要か

- 有機物は必要か？
  - 植物は無機から有機を作る
  - 植物は無機態の養分元素を吸収する
  - 有機物の構成の大半はC H O
  - 圃場養分の不確実化
  - 土壌有機物は土壌微生物の餌となる
  - 水分子の保持力が上がる
- 土壌表面に散布する物質がどこに行く？
- 砂粒子（石）表面にへばりつくもの・・・



# 地表面で起こること

- 地表面には水は不要
- 根圏に水が必要
- 藻、コケ
- 病害発生
- 根が浅くなる
  - 水・養分の吸収量減
  - 頻繁な散水

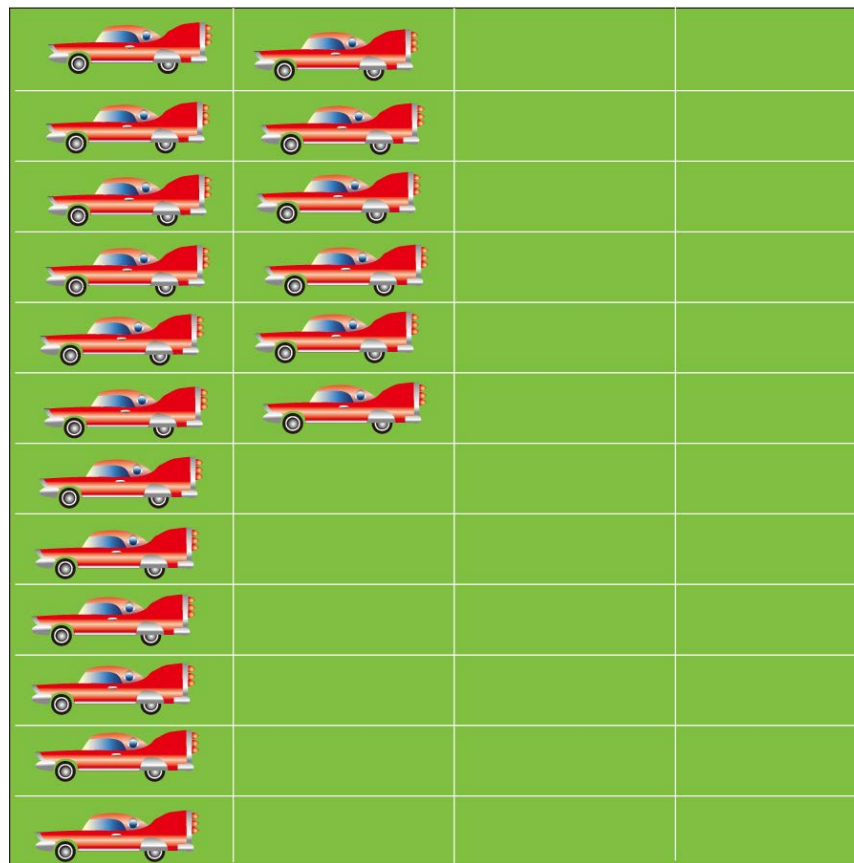


# CEC(陽イオン交換容量)

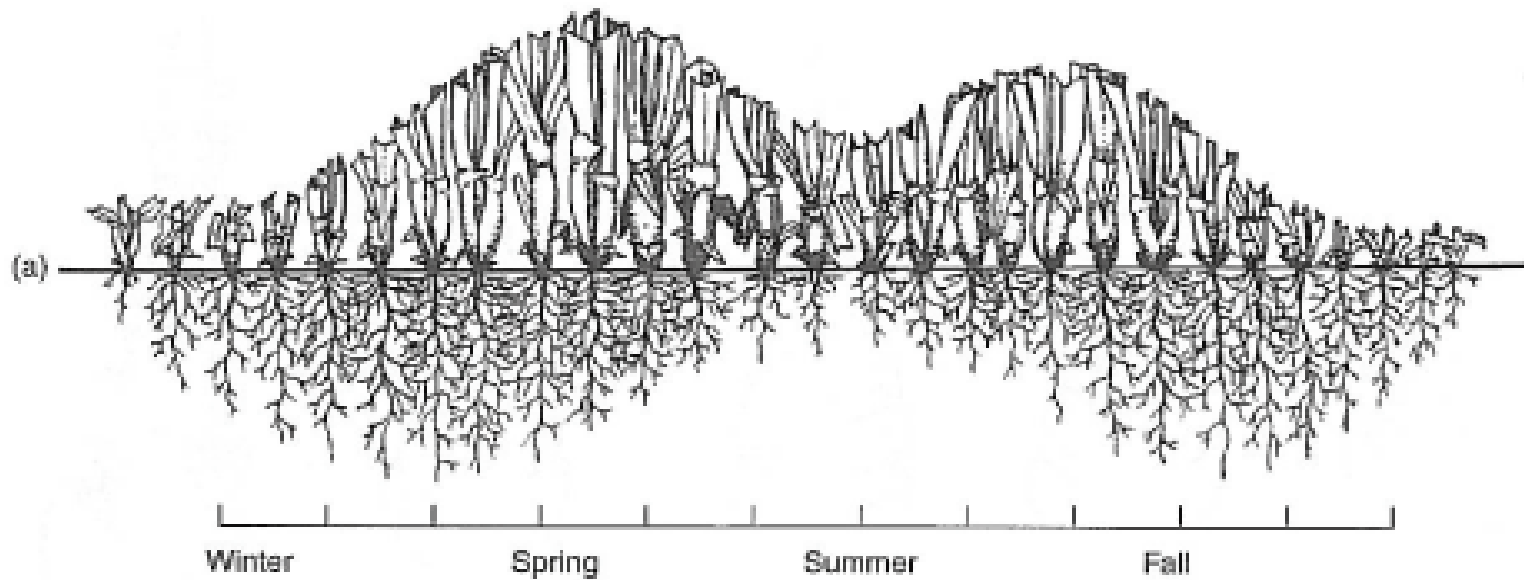
$$\text{CEC} = \text{有機物}\% \times 2.5 + \text{粘土鉱物}\% \times 0.57$$

# 陽イオン飽和度

|           |        |
|-----------|--------|
| $K^+$     | 5%     |
| $Mg^+$    | 15-20% |
| $Ca^{++}$ | 65-75% |
| $Na^+$    | <5%    |



# 寒地型芝の成長







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REPORT NUMBER: 16-263-097

GROWER: N-TOKYO

SEND TO: HUGH ENTERPRISES LTD  
5-28 SHINOGAWAMACHI  
SHINJUKU-KU TOKYO

SUBMITTED BY:

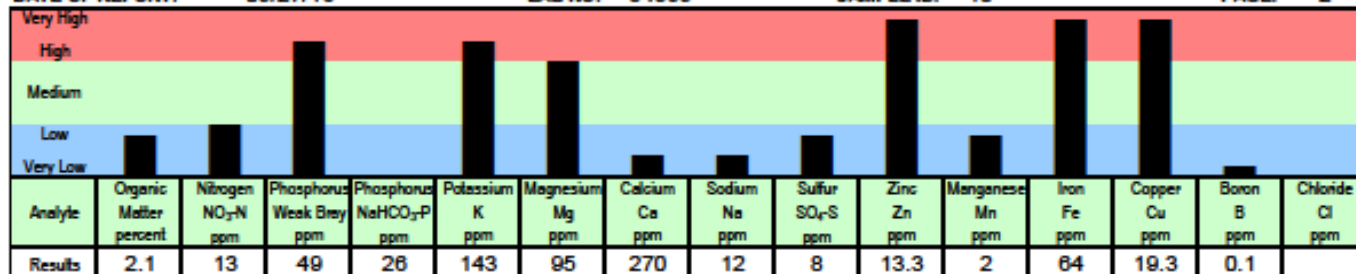
## Graphical Soil Analysis Report

DATE OF REPORT: 09/27/16

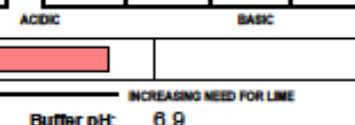
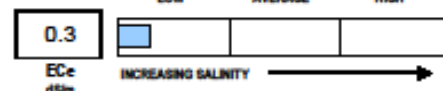
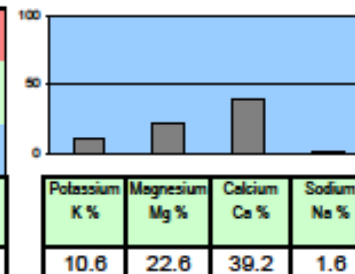
LAB NO: 54399

SAMPLE ID: 18

PAGE: 2



## Percent Cation Saturation (computed)



NaHCO<sub>3</sub>-P unreliable at this soil pH

## Soil Fertility Guidelines

CROP: BENTGRASS

RATE:

NOTES:

| Dolomite (70 score) | Lime (70 score) | Gypsum | Elemental Sulfur | Nitrogen N | Phosphate P <sub>2</sub> O <sub>5</sub> | Potash K <sub>2</sub> O | Magnesium Mg | Sulfur SO <sub>4</sub> -S | Zinc Zn | Manganese Mn | Iron Fe | Copper Cu | Boron B |
|---------------------|-----------------|--------|------------------|------------|-----------------------------------------|-------------------------|--------------|---------------------------|---------|--------------|---------|-----------|---------|
|                     | 0               |        |                  | 2.5        | 0.5                                     | 1.2                     |              | 0.3                       |         | *            |         |           | *       |

- C** TEES and GREENS may require over 6 lb N/1,000 sq ft per season (or even more if bermudagrass), whereas
- O** FAIRWAYS may be less, depending on local conditions and variety of turf.
- M** MICRONUTRIENTS: Where levels appear to be high, avoid any further applications for the time being. Very
- M** high (VH) levels may not necessarily be toxic, but avoid. Maintain correct soil pH.
- E** \* BORON may not necessarily be deficient in the soil, and it is hard to correct an excessive
- N** application. Therefore, apply boron only if confirmed deficient through a leaf analysis.
- T** \* MANGANESE: The soil test is not a good indicator of deficiency. Maintain a reasonable soil pH and
- S** organic matter status, and follow label directions if applying manganese-containing products.

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*Phoebe Gordon*

Phoebe Gordon, PhD  
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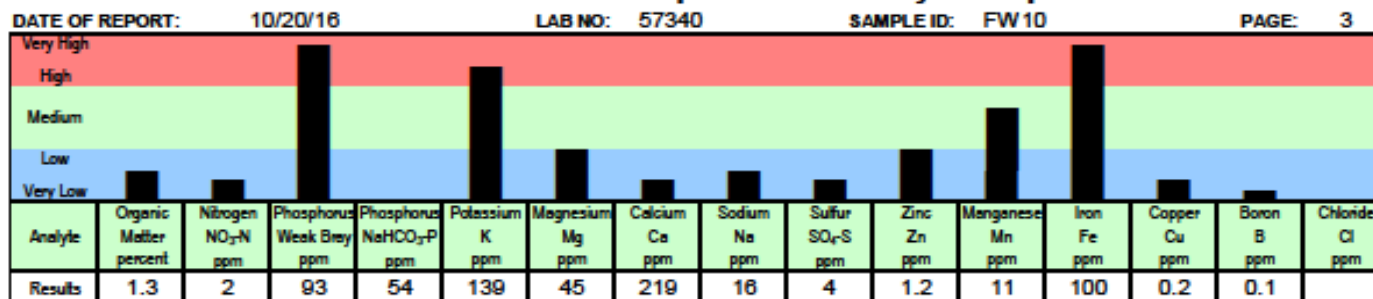
REPORT NUMBER: 16-288-097

GROWER:

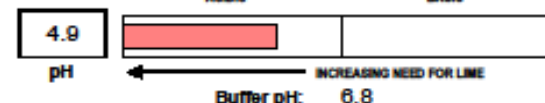
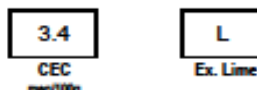
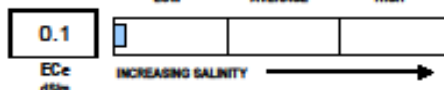
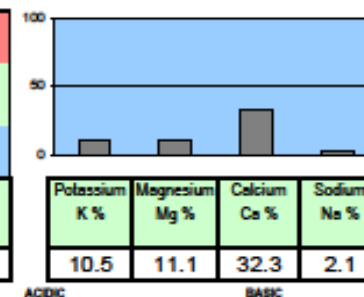
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## Graphical Soil Analysis Report



## Percent Cation Saturation (computed)



NaHCO<sub>3</sub>-P unreliable at this soil pH

## Soil Fertility Guidelines

CROP: BENTGRASS

RATE: lb/1000 sq ft

NOTES:

| Dolomite (70 score) | Lime (70 score) | Gypsum | Elemental Sulfur | Nitrogen N | Phosphate P <sub>2</sub> O <sub>5</sub> | Potash K <sub>2</sub> O | Magnesium Mg | Sulfur SO <sub>4</sub> -S | Zinc Zn | Manganese Mn | Iron Fe | Copper Cu | Boron B |  |
|---------------------|-----------------|--------|------------------|------------|-----------------------------------------|-------------------------|--------------|---------------------------|---------|--------------|---------|-----------|---------|--|
| 20                  |                 |        |                  | 5.7        |                                         | 2.5                     |              | 0.6                       |         |              |         | *         | *       |  |

**C** \* BORON may not necessarily be deficient in the soil, and it is hard to correct an excessive application. Therefore, apply boron only if confirmed deficient through a leaf analysis.

**O**

**M** MICRONUTRIENTS: Where levels appear to be high, avoid any further applications for the time being. Very

**M** high (VH) levels may not necessarily be toxic, but avoid. Maintain correct soil pH.

**E** PLEASE NOTE THAT THE PREVIOUS COMMENTS WHERE APPLICABLE, APPLY TO THE ENTIRE REPORT. THANK YOU.

**N**

**T**

**S**

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# pH

- 水素イオン濃度指数
- $\text{pH} = -\log[\text{H}]$
- 水素濃度 高い＝酸性、低い＝アルカリ性
- pH1酸性、pH10アルカリ性
- 塩基性＝OH
- 土壌のpHは土壌中の水素イオン＝ $\text{H}^+$



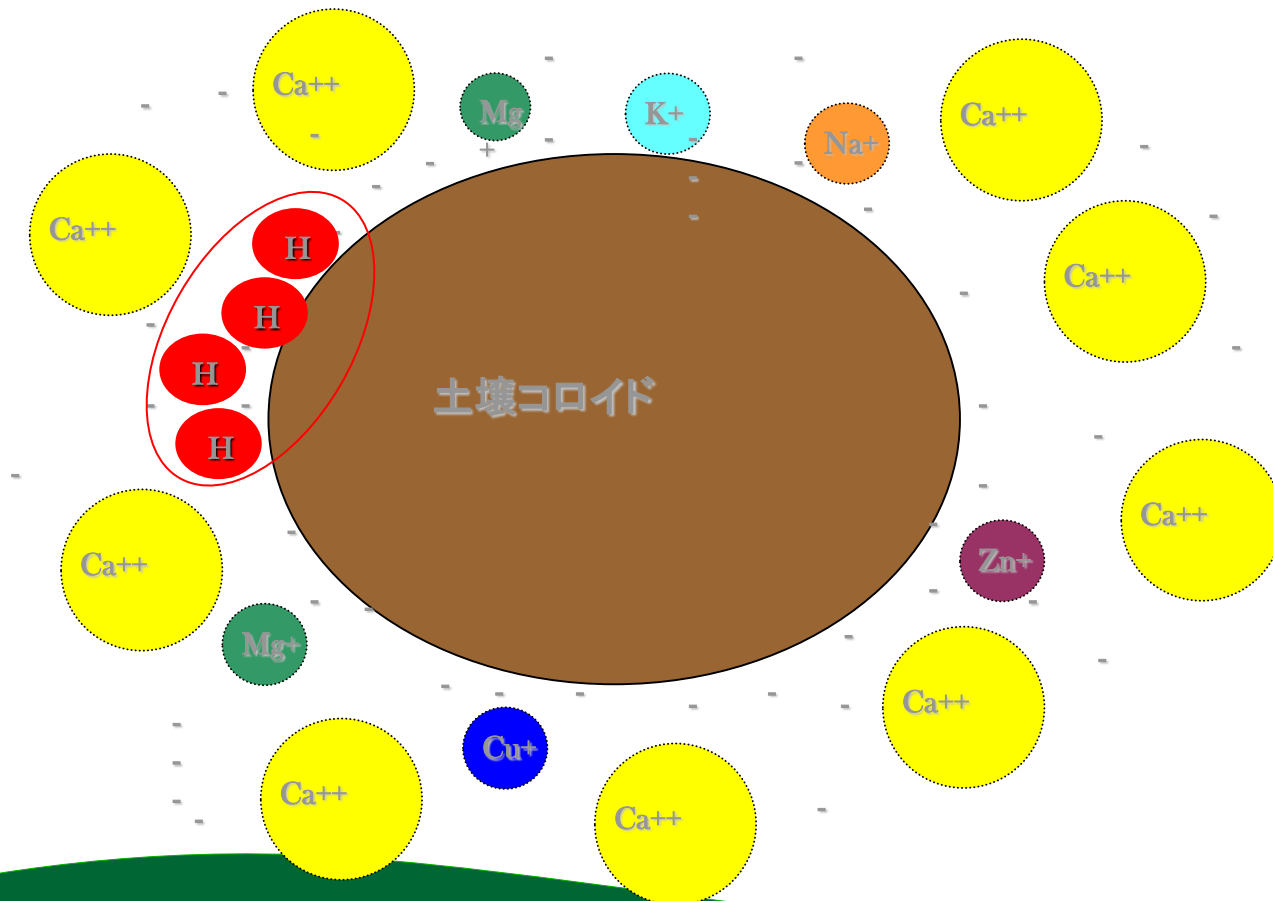
# pH



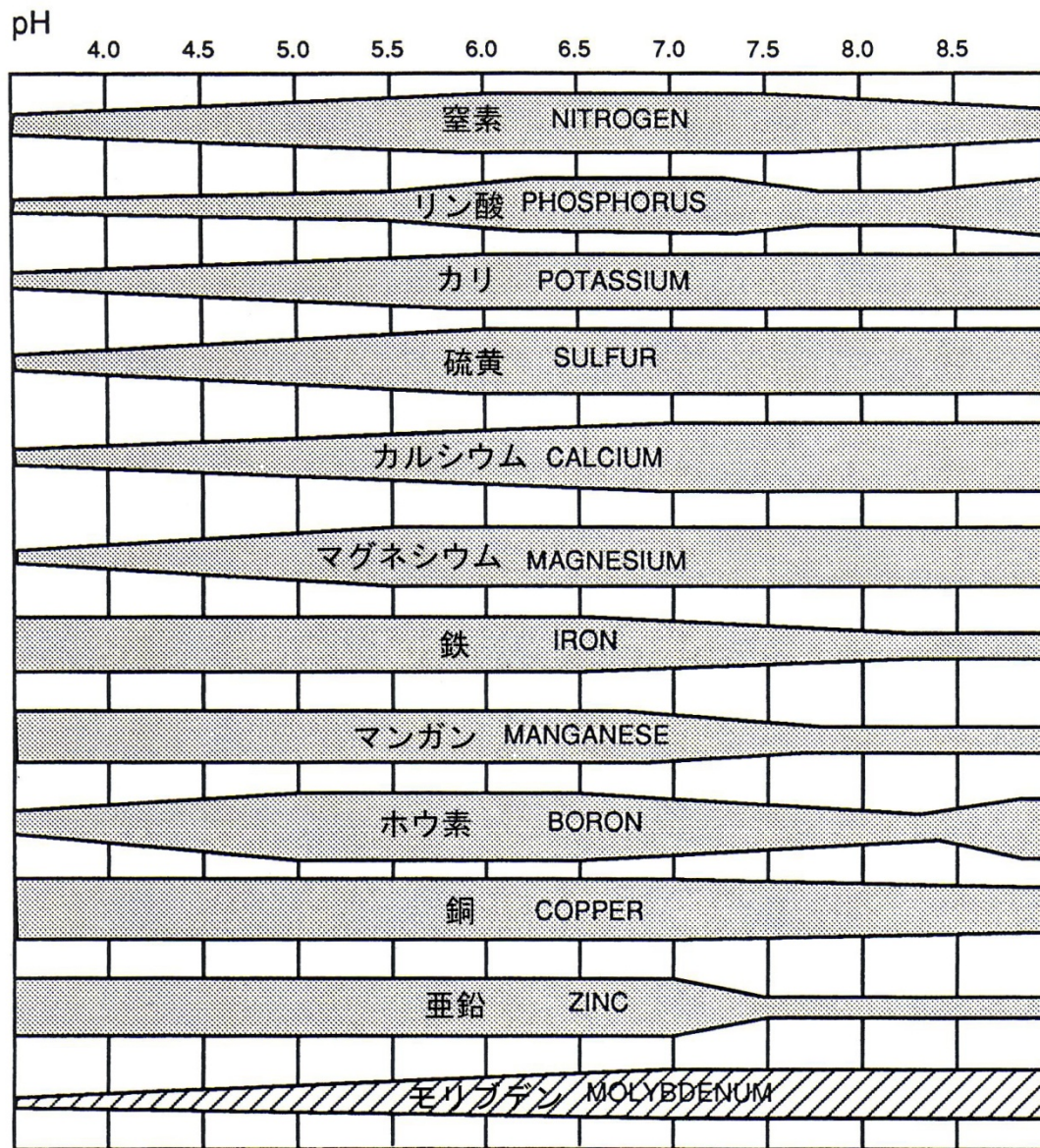
- 水酸化カルシウム  $\text{Ca}(\text{OH})_2$  消石灰(slaked lime)

# pH は水素イオンの量を示します

is a measurement of the hydrogen ion concentration



# pHによる利用可能養分



**TABLE 2-3. Range of pH Values for Several Common Substances**

| H <sup>+</sup><br>Concentration<br>(moles per liter) | pH | OH <sup>-</sup><br>Concentration<br>(moles per liter) | Examples              | pH   | Description                                                                          |
|------------------------------------------------------|----|-------------------------------------------------------|-----------------------|------|--------------------------------------------------------------------------------------|
| $1 \times 10^{-14}$                                  | 14 | 1.0                                                   | Lye (bleach)          | 13.0 | Strong alkaline                                                                      |
| $1 \times 10^{-13}$                                  | 13 | $1 \times 10^{-1}$                                    | Household ammonia     | 12.0 |   |
| $1 \times 10^{-12}$                                  | 12 | $1 \times 10^{-2}$                                    | Milk of magnesia      | 10.5 |                                                                                      |
| $1 \times 10^{-11}$                                  | 11 | $1 \times 10^{-3}$                                    | Soap                  | 9.3  |                                                                                      |
| $1 \times 10^{-10}$                                  | 10 | $1 \times 10^{-4}$                                    | Antacid tablets       | 9.4  |                                                                                      |
| $1 \times 10^{-9}$                                   | 9  | $1 \times 10^{-5}$                                    | Baking soda           | 8.0  |                                                                                      |
| $1 \times 10^{-8}$                                   | 8  | $1 \times 10^{-6}$                                    | Seawater              | 7.9  |                                                                                      |
|                                                      |    |                                                       | Human blood           | 7.3  |                                                                                      |
| $1 \times 10^{-7}$                                   | 7  | $1 \times 10^{-7}$                                    | Pure water            | 7.0  | Neutral                                                                              |
| $1 \times 10^{-6}$                                   | 6  | $1 \times 10^{-8}$                                    | Fresh milk            | 6.7  | Weak acids                                                                           |
| $1 \times 10^{-5}$                                   | 5  | $1 \times 10^{-9}$                                    | Rain                  | 5.6  |                                                                                      |
| $1 \times 10^{-4}$                                   | 4  | $1 \times 10^{-10}$                                   | Sour milk             | 4.7  |  |
| $1 \times 10^{-3}$                                   | 3  | $1 \times 10^{-11}$                                   | Beer                  | 4.4  |                                                                                      |
| $1 \times 10^{-2}$                                   | 2  | $1 \times 10^{-12}$                                   | Coffee & Tomato juice | 4.2  |                                                                                      |
| $1 \times 10^{-1}$                                   | 1  | $1 \times 10^{-13}$                                   | Orange juice          | 3.7  |                                                                                      |
| 1.0                                                  | 0  | $1 \times 10^{-14}$                                   | Wine                  | 3.5  |                                                                                      |
|                                                      |    |                                                       | Vinegar               | 2.9  |                                                                                      |
|                                                      |    |                                                       | Classic Coke          | 2.5  |                                                                                      |
|                                                      |    |                                                       | Lemon juice           | 2.4  |                                                                                      |
|                                                      |    |                                                       | Gastric juice         | 2.0  |                                                                                      |
|                                                      |    |                                                       | Battery acid          | 0.5  |                                                                                      |
|                                                      |    |                                                       |                       |      | Strong acids                                                                         |



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