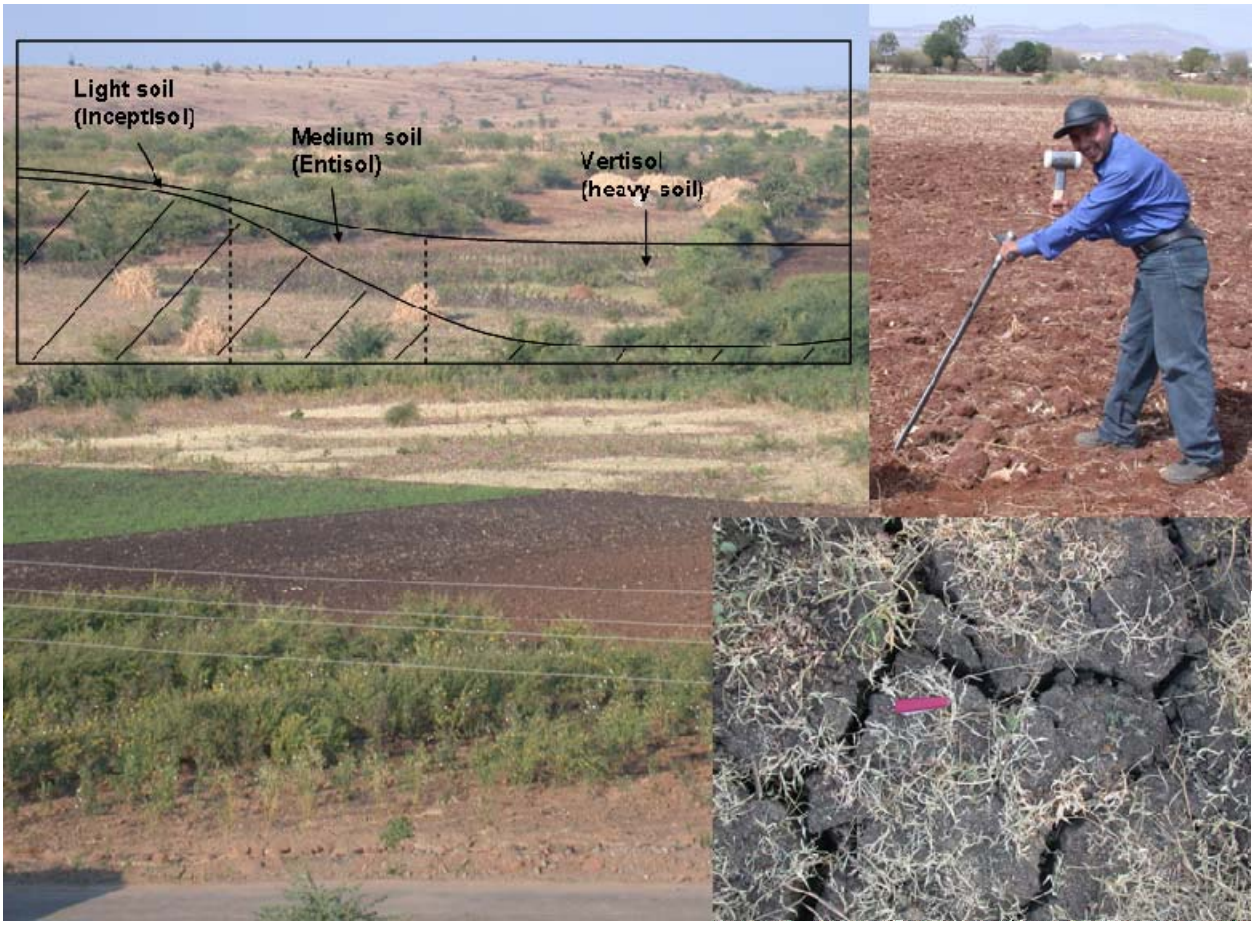
Soil Fertility Training Manual

Soil Properties, Soil Fertility Management and Plant Nutrition in Organic Cotton

Frank Eyhorn



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Training Manual on Soil Fertility

Soil Properties, Soil Fertility Management and Plant Nutrition in Organic Cotton

Frank Eyhorn, FiBL

1st Edition, June 2005

Contents of the training manual

This training manual consists of:

- A curriculum for a one day training cum workshop;
- A collection of transparencies, with explanations (see notes to each transparency);
- A soil assessment questionnaire.

Aim and target group

This training manual shall facilitate trainings / workshops on soil basics relevant in organic cotton farming. The target group are extension staff of organic cotton projects in the tropics.

How to use the training manual

The curriculum provides an example of a one day training schedule, indicating the topics and contents to be covered, objectives of each session, suggested training methods and necessary preparations. It refers to the transparencies (Power point) that illustrate the respective topics. The content of each transparency is described in the notes given in the notes below the transparency. Resource persons are encouraged to adapt the curriculum and transparencies to the requirements of their target group and to the specific conditions.

Copies can be downloaded (for free) or ordered from www.shop.fibl.org. A Hindi translation is available from www.iccoa.org.

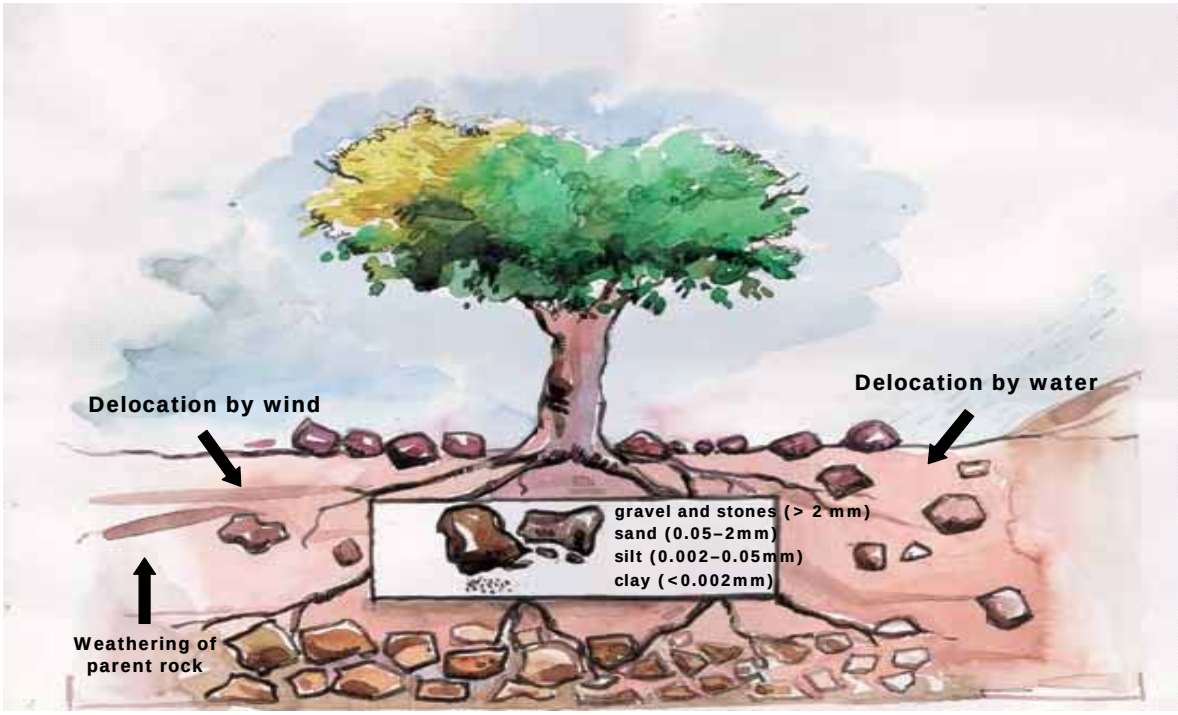
An output of the Maikaal Organic Cotton Research Project.
Further information: www.organiccotton.fibl.org

1.1 Curriculum for a one-day Training / Workshop on Soil (Example)

Time	Topic	Contents	Objectives	Method	Preparations
8.45	Assembling	Preparations	Getting ready	Distribute handouts	Handouts
9.00	Welcome, Introduction to the training	Idea, aims, program, "rules"	Motivation, overview on expectations of participants, approval of program and rules	Handout of program, transparencies 1 and 2, Introduction round	OHP, slides, handout of program and of documentation
9.20	The importance of soil	Brainstorming (Ask: Why is it important for their work to know about soil?)	Motivation, ice breaking	Brainstorming with participants, note on white board	White board
9.30	Soil basics	Texture, organic matter, micro-organisms, mycorrhiza, exchange capacity	Basic understanding of soil, importance of soil organic matter	OHP presentation of transparencies 3-10, Discussion on how to increase soil organic matter (transparency 11)	Transparencies
10.00	Familiarizing with soil (practical exercise with soil samples)	Soil properties Soil fertility assessment	Get a feeling for the different types of soil; relate visual properties with fertility properties	In groups of 3-4, select a sample, discuss it with the help of the soil assessment questionnaire	Table with soil samples and labels, copies of soil assessment questionnaire
10.30	Tea break				
11.00	Presentation of group work	ditto	ditto	2-3 groups present their findings to the plenum	
11.15	Soils in the project region	Relation of soil type with topography; soil types and their properties	Understand which soil is on which site; and its relevance for farm management	Transparency 12, show samples of 3 main types; transparencies 12 – 15	Bowls with the three main soil types, transparencies
11.30	Group work: soil properties and soil fertility managem.	Soil specific management practices	Understand the relation of soil properties and farm management	Introduce group work with transparency 16; form 3 groups, each takes a soil sample and fills in the chart	3 charts, prepared with topics, marker pens, tables and chairs
12.00	Presentation of group work	ditto	ditto	Presentation in plenum (each 5-10 min); summary with transparency 17	Place to hang charts, tape or pins
12.30	Lunch break				

Time	Topic	Contents	Objectives	Method	Preparations
13.30	Crop nutrition	Nutrient requirements of crops Availability of nutrients	Understanding the concept of nutrient availability; understanding the significance and limitations of soil tests	Ask the participants: which are the important nutrients? Note them down. Presentation of transparencies 18 – 23; show plants with deficiency symptoms	White board OHP Collect cotton plants with nutrient deficiency symptoms
14.00	Organic manures and natural mineral fertilizers	Nutrient contents of manures and fertilizers	Know-how on manures and fertilizers	Ask which manures and fertilizers the know; discuss their significance, advantages and disadvantages. Summarize with transparency 24	Board for noting down the manures/fertilizers; OHP
14.30	Group work: Timing of manure application	Appropriate timing, considering the time needed for decomposition of the manure	Understand that the timing of manure application in organic farming is different from conventional farming	Ask the participants to draw the curves for nutrient requirement and ideal manure application in cotton on charts. (in 3 groups)	Charts for drawing the timing of manure application (draw axis)
15.00	Tea break				
15.30	Presentation of Group work	ditto	ditto	Each group presents their chart, compare with transparency 25	Place to hang charts, tape or pins
15.45	Nitrogen Fixation and Nitrogen Immobilisation	Nitrogen fixation by plants; N-Immobilisation: What? why? how to avoid?	Fresh-up N-fixation; understanding why temporary N-deficiency can occur and how to avoid	Ask: who can explain nitrogen fixation? Transparencies 26 – 27; Discussion	Transparencies show legumes with nodules
16.15	Feedback to the training/workshop	Brief review of the day, what did we learn? Rating of the training / workshop; evaluation	Reflection on what we did today; get feedback for improving the training	One participant to summarize the day; stick points on chart to the statement where they agree; discussion	Chart with statements about the usefulness of the training / workshop; points to stick for voting
16.45	End of the training				

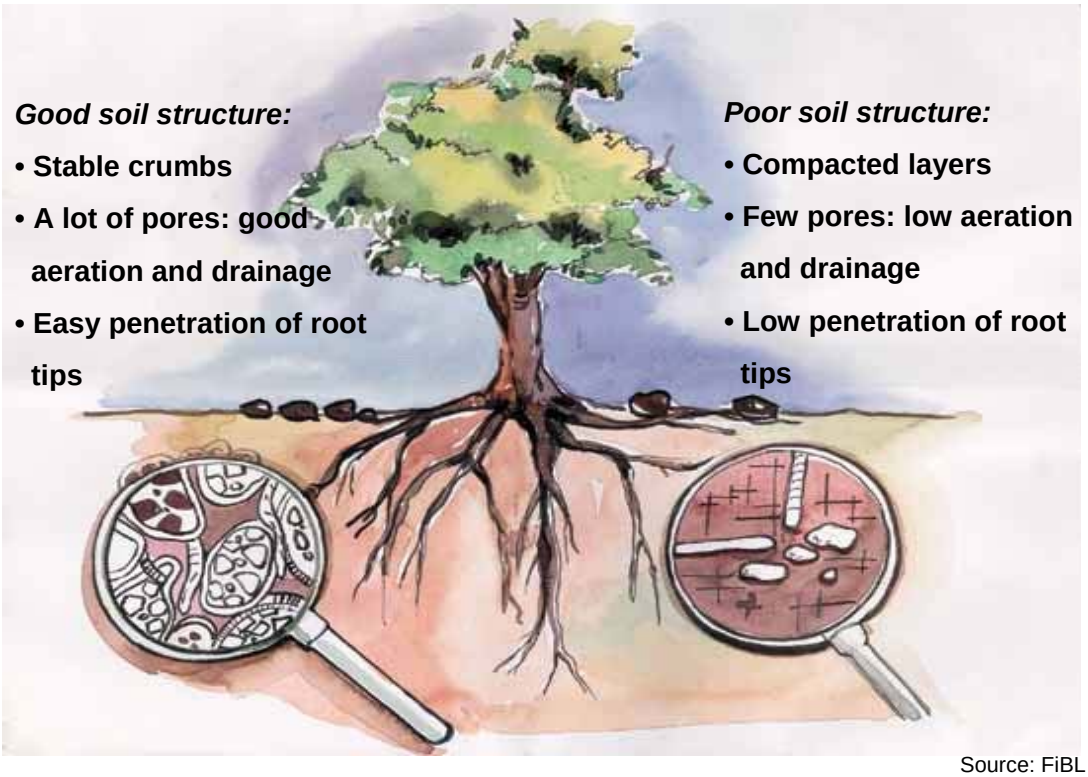
Texture - Mineral particles



Source: FiBL / IFOAM

- **The basis of the soil are its mineral particles. They originate from weathering of parent rock, which is a slow but continuous process as long as parent rock is present.**
- **Water and wind relocate soil from one place to an other, e.g. as soil erosion or as accumulation of soil in depressions.**
- **Soil particles are classified by size:**
    - **Gravel (> 2mm)**
    - **Sand (0.05 – 2 mm)**
    - **Silt (0.002 – 0.05 mm)**
    - **Clay (> 0.002 mm)**
- **For the fertility of the soil, the fine particles (clay and silt) are most important, as they hold moisture and nutrients.**

Soil structure – What does it mean?



Source: FiBL / IFOAM

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Soil Basics (4)

- **Soil structure means the spatial arrangement of the soil components, i.e. the mineral particles and the pores filled with air or water, into crumbles, blocks etc.**
- **The graph indicates what is meant by good soil structure (left) and poor soil structure (right), illustrated by the soil sections in the two magnifying glasses**

The soil micro-cosmos

Larger soil organisms:

- **Pull dead biomass into the soil**
- **Feed on organic materials and mix them with the soil**
- **Dig tunnels and facilitate aeration and drainage**

earthworm

slater

spring tail

mite

milipedes

slug

Soil Micro-organisms:

- **Decompose organic matter**
- **Improve the soil structure**
- **Make nutrients available for plants**
- **Protect the plants from disease attack**

Source: FiBL / IFOAM

Soil Basics (5)

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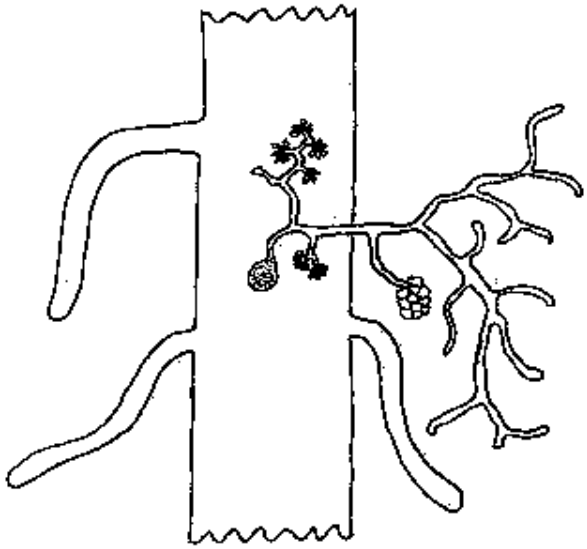
- **Soil organisms play a crucial role for soil fertility. Most of them are very useful, only few cause damage to crops.**
- **The text describes the main functions of the larger (visible) soil organisms (left) and of the soil micro-organisms (right, illustration in magnifying glass) which are not visible with the naked eye**

Mycorrhizza – A beneficial fungus



Mycorrhizae...

- **Live in symbiosis with plant roots.**
- **Enlarge the surface of the roots and penetrate small soil pores.**
- **Support the plants in taking up nutrients and water.**
- **Improve the soil structure and preserve moisture.**
- **Are affected by chemical fertilizers and pesticides.**

Source: FiBL / IFOAM

Soil Basics (6)

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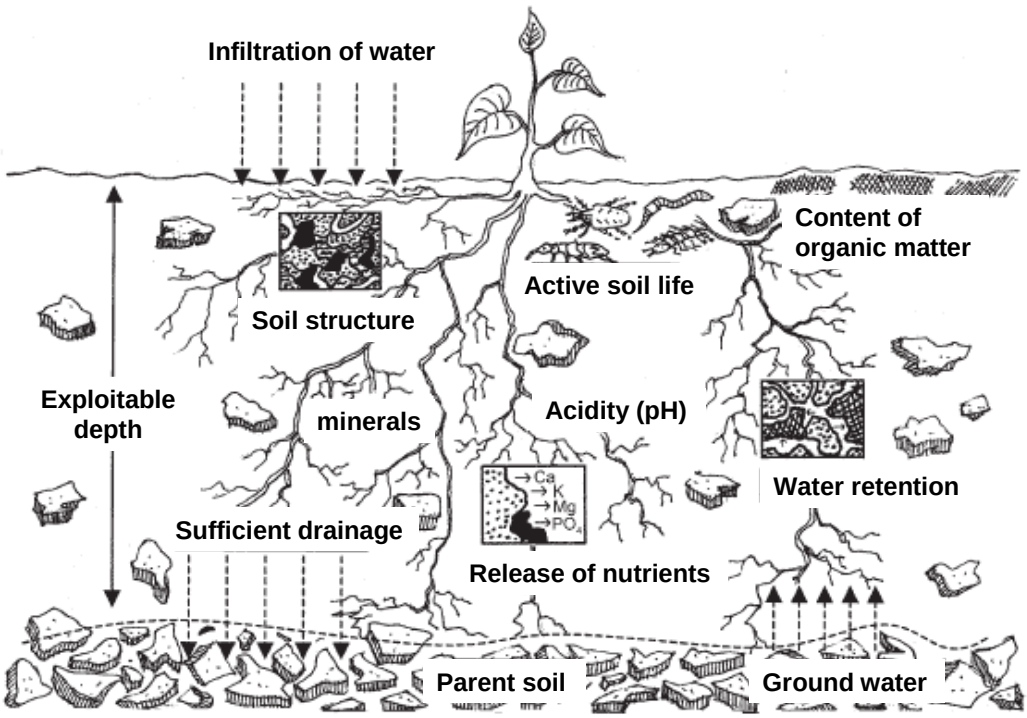
- **Mycorrhiza is a fungus living in association (symbiosis) with plant roots. They occur naturally in most soils and support plant growth.**
- **The graph shows a section through a plant root, which hosts the mycorrhiza fungus. Mycorrhiza is very small and can only be seen with a microscope.**
- **The number of effective mycorrhiza in a field can be increased through application of inoculums, which are commercially sold.**

Factors influencing soil fertility

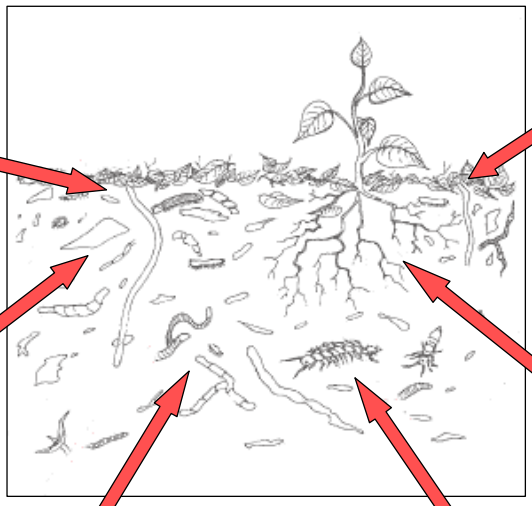


Source: FiBL / IFOAM

Soil Basics (7)

- **Soil fertility depends on a number of factors, as listed and illustrated on this illustration of a soil section.**
- **The boxes show magnified soil sections in a schematic way.**
- **Arrows indicate directions of move.**

Why is organic matter so important?



Source: FiBL / IFOAM

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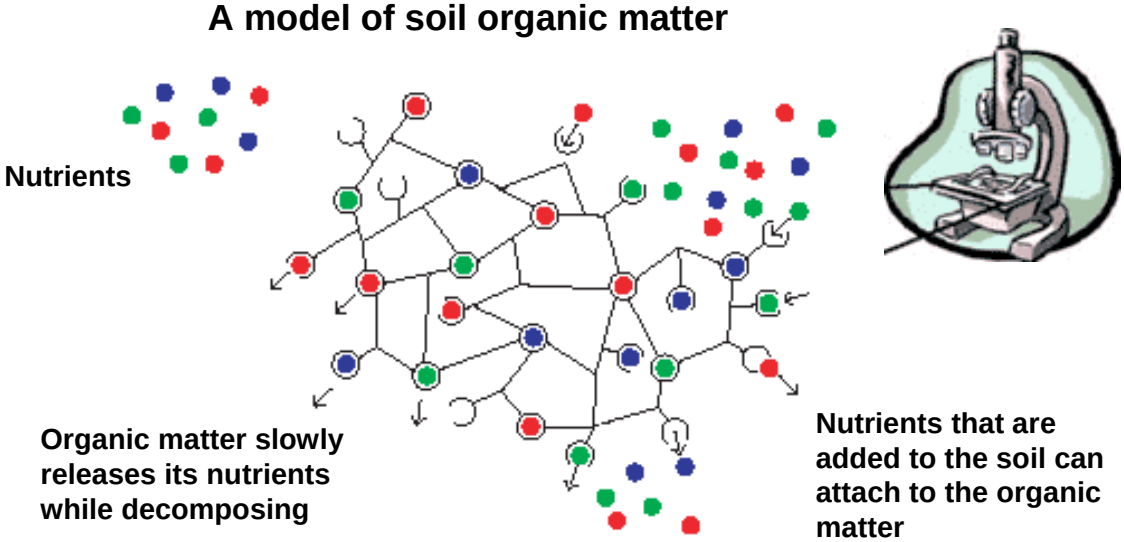
Soil Basics (8)

- **Organic matter in the soil is the remains of plant, dung or animal residues after partial decomposition. It is of brownish-blackish colour and of crucial importance for soil fertility.**
- **The various functions of soil organic matter are given in the text boxes, pointing to the soil section illustrating the respective aspect.**

Organic matter: Retaining and releasing nutrients

A model of soil organic matter

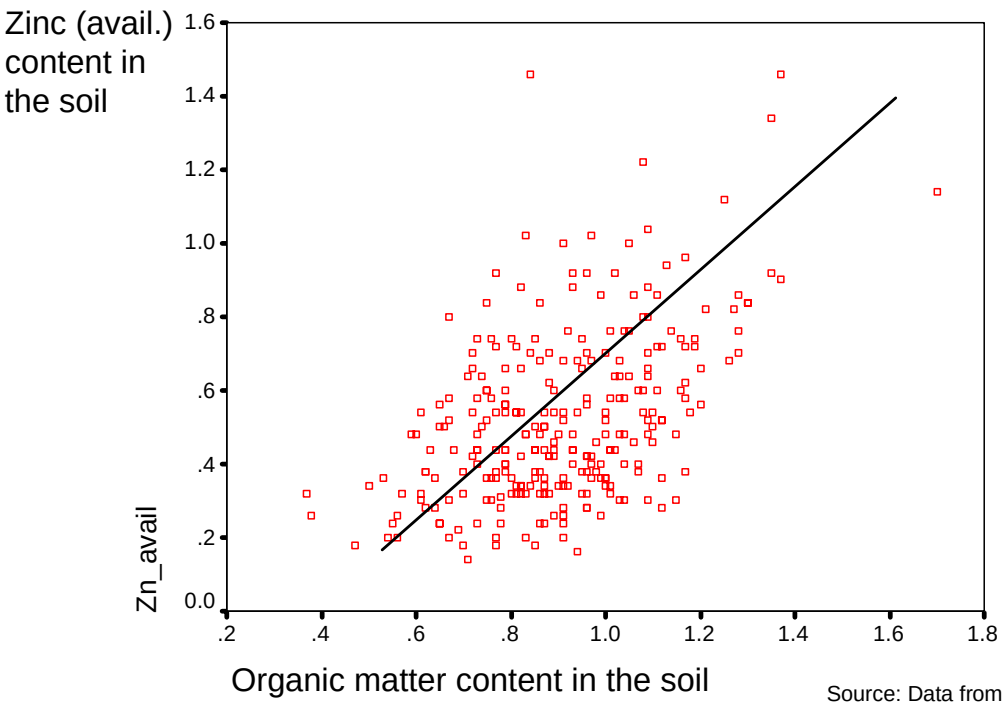


Source: FiBL / IFOAM

Soil Basics (9)

- **Organic matter has a complex chemical structure, consisting of large molecules. The drawing provides a simple model on how this structure might look if it could be seen through a microscope (which it can not).**
- **The coloured dots represent different nutrients (e.g. N, P, K etc.)**
- **Arrows indicate possible movements: attachment (nutrient holding capacity) and release (decomposition and nutrient exchange)**

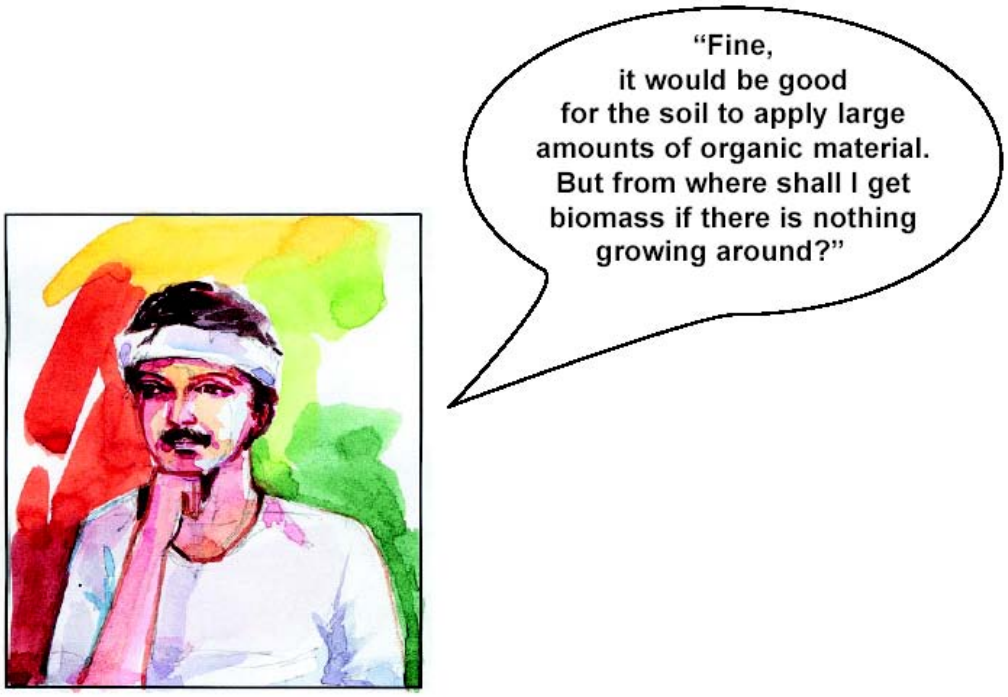
Example: Korrelation between Zinc and organic matter content



Source: Data from the Maikaal Organic Cotton Research Project

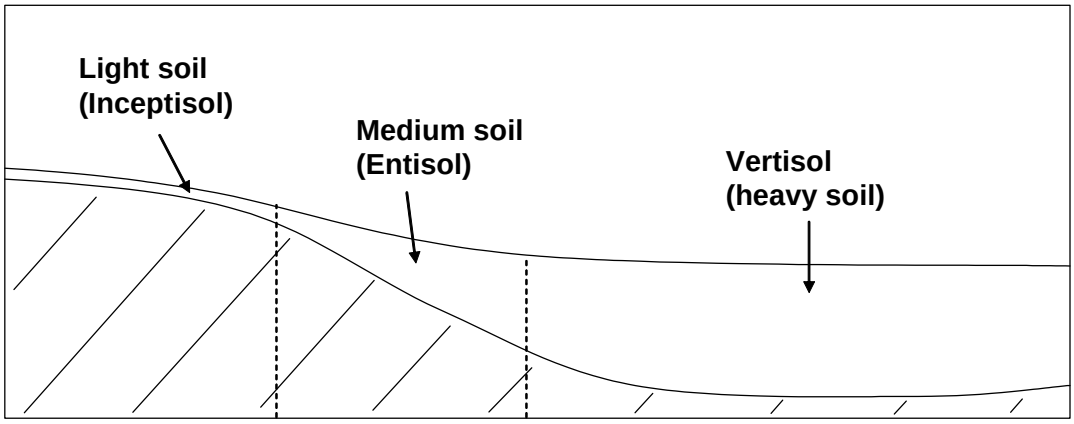
- **The graph shows the values of available Zinc in correlation with organic matter content in about 200 soil samples taken in organic and conventional cotton fields in the Maikaal project.**
- **This shows: the more organic matter, the more available Zinc.**
- **As Zinc, many nutrients attach to soil organic matter and are thus available to the plant.**

A farmer's voice



- **Illustration to stimulate discussion on how farmers can increase the organic matter content in the soil.**
- **Discuss possible options with the participants.**

Soil topo-sequence in the Nimar region, India



Inceptisols:

- Light sandy soils
- Low clay content
- Shallow
- Low nutrient exchange capacity

Entisols:

- Medium clay content
- Dark or brown
- Medium depth

Vertisols (black cotton soil):

- High clay content
- Deep (one to several meters)
- High water holding capacity
- High nutrient exchange capacity
- swell- and shrink properties

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- **The graph shows a typical cross section of a region in Central India, but the situation will be similar in many areas.**
- **On elevations over parent rock, soils are usually more shallow and more rich in sand than the soils in depressions. Fine soil material (silt and clay) gets washed out from elevated sites and accumulates in depressions. Thus, soils become more deep and more rich in silt and clay.**

Taking soil samples in a topo-sequence

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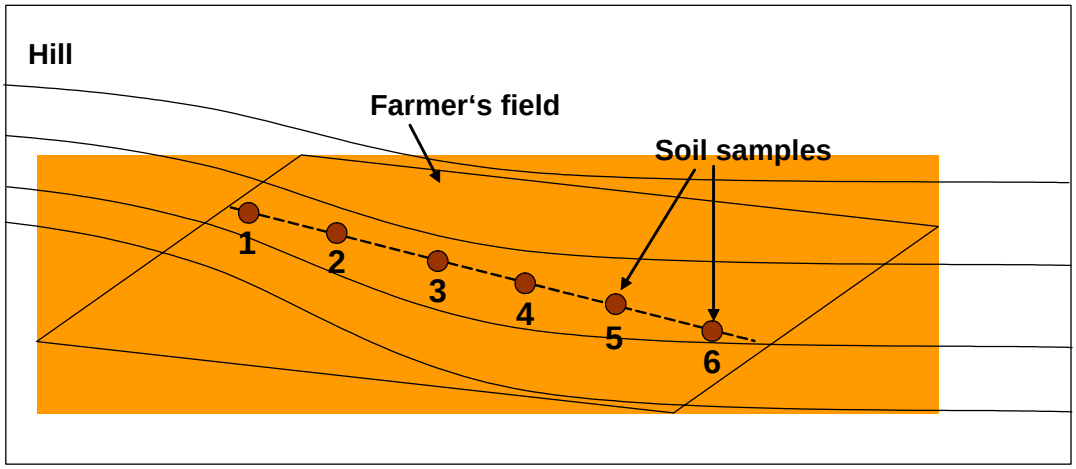
Soil Basics (13)

- **The following three transparencies illustrate how soil properties change along a topo-sequence (going from elevations to depressions).**
- **The researchers have taken six soil samples in the field shown in the picture. (next slide: schematic illustration)**

Soil samples in a topo-sequence in a farmer‘s field



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- **A schematic illustration of the six soil samples taken in the uneven field (next slide: results)**

Results of soil samples in a topo-sequence

Sample No.	Depth (cm)	Sand (%)	Clay (%)	WRC (%)	Corg (%)
	Soil depth	coarse particles	fine particles	Water retention capacity	Organic carbon content
1 uphill	7	87	4	29.0	0.26
2	10	87	6	28.6	0.13
3	15	79	8	33.1	0.13
4	28	69	14	41.4	0.19
5	55	67	18	50.9	0.58
6 downhill	> 100	65	22	66.7	0.58

Source: Data from Maikaal Organic Cotton Research Project

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- **The analysis results of the six samples are given in the table.**
- **When moving downhill, the depth of the soil increases, and soils get less sandy and more rich in clay. The water retention capacity and the organic matter content also increase, as both are linked (correlated) with the clay content of the soil.**

Soil properties and soil management – Group work

Soil type: ☐ light ☐ medium ☐ heavy

Properties:

Soil depth:
Water retention capacity:
Nutrient holding capacity:

Crop selection:

Which crops are suitable?

Which cotton varieties are suitable?

Suitable crop rotations? intercrops?

Soil management:

Main purpose for applying compost?
Amount of compost to apply?
Soil cultivation?
Risk of soil erosion?

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- **Introduction of the group work: soil properties and soil management**
- **For each group, prepare a paper chart with the points given on the transparency**

Soil Assessment Questionnaire	
Name and origin of the soil sample:	
Tactile properties (Feel it!) ***Take a teaspoon of soil in your hand, add some drops of water, probe between fingertips:*** - Gritty? → rich in sand - Smooth and sticky? → rich in clay ***Try to make a firm square of soil. Next, try to roll up the square into a thin roll.*** - Roll is not possible → sand or sandy loam - Roll is possible → loam or clay soil ***If a roll was possible, try to bend the roll into a ring.*** - Ring not possible → loam or loamy clay - Ring possible → clay soil	*How does the soil feel between your fingers?* *Is the soil sticky enough to form a square and a roll?* *Is it possible to form a stable ring?*
Visual properties (Look at it!) Describe the colour of the soil. What might be the reason for the colour?	
Site information From which region does it come? On which kind of place will you usually find this type of soil?	
Agricultural use Will it keep the water well? Will it be easy or difficult to plough/cultivate this soil? Is it rich in nutrients?	
Your overall assessment: How fertile is this soil? Remarks:	

Soil types and their properties: Summary

Light Soils	Heavy Soils
Low water retention capacity → affected by droughts!	High water retention capacity → less risk of drought
Sandy, easy to cultivate	Rich in clay; muddy when wet, hard when dry
Nutrients easily get washed out → need sufficient compost; supply of mineral fertilizers in several doses	Very fertile - Need sufficient manure because of high productivity
Non-hybrid cotton varieties (desi varieties)	Hybrid cotton varieties
Drought resistant rotation crops: sorghum, maize, pigeon pea, millets, moong bean, castor	High performance rotation crops: chilli, soya bean, banana, sugar cane, wheat etc.
Intercrop to reduce risk of crop failure	Intensive crop rotation; green manures
Compost and mulching to improve water holding and nutrient supply	Compost to activate soil live and improve soil structure
Shallow ploughing, few soil cultivation	Deep ploughing, frequent shallow soil cultivation (intercultural operations)
Increase infiltration through trenches and bunds	Risk of water logging!

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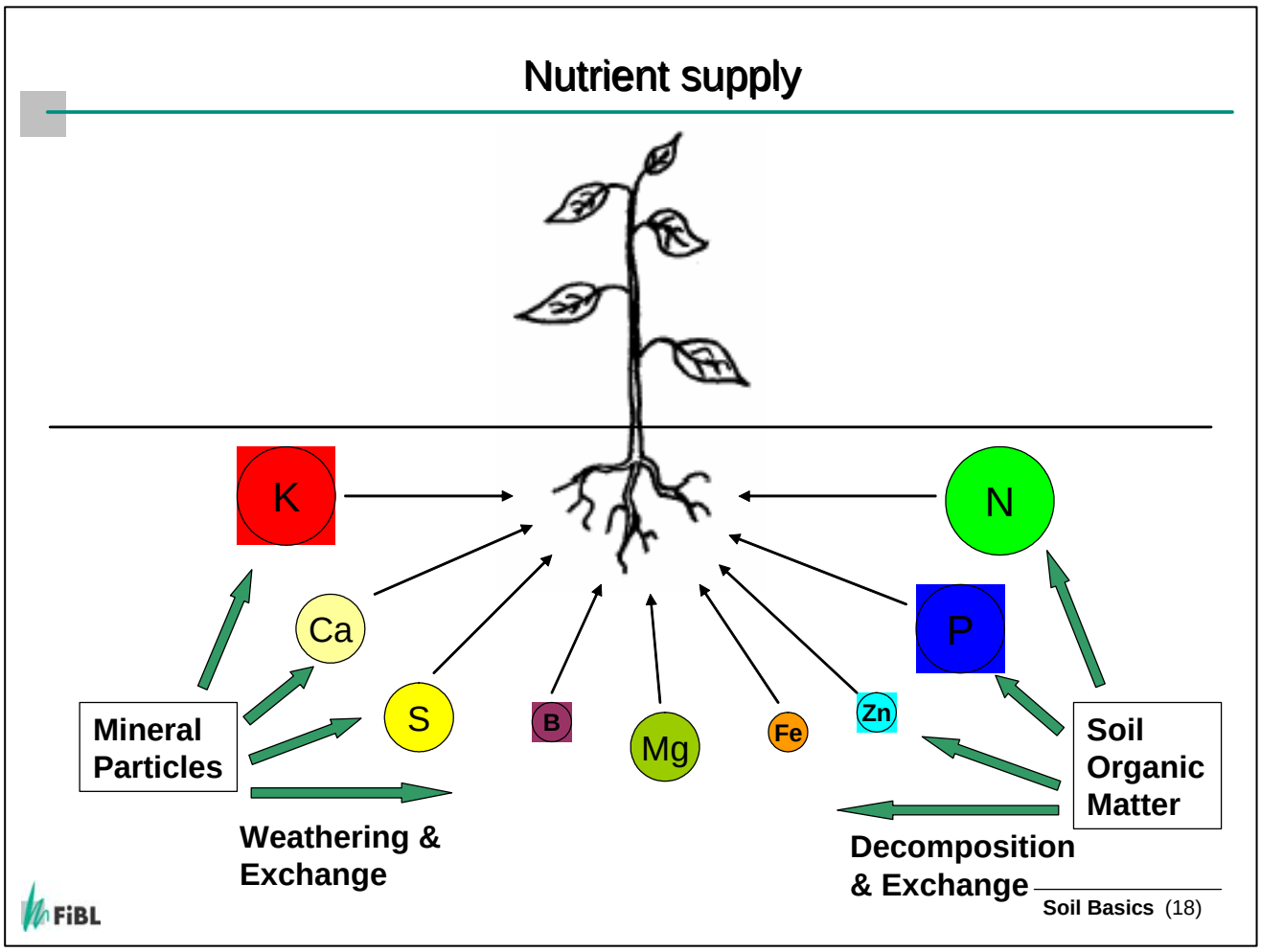
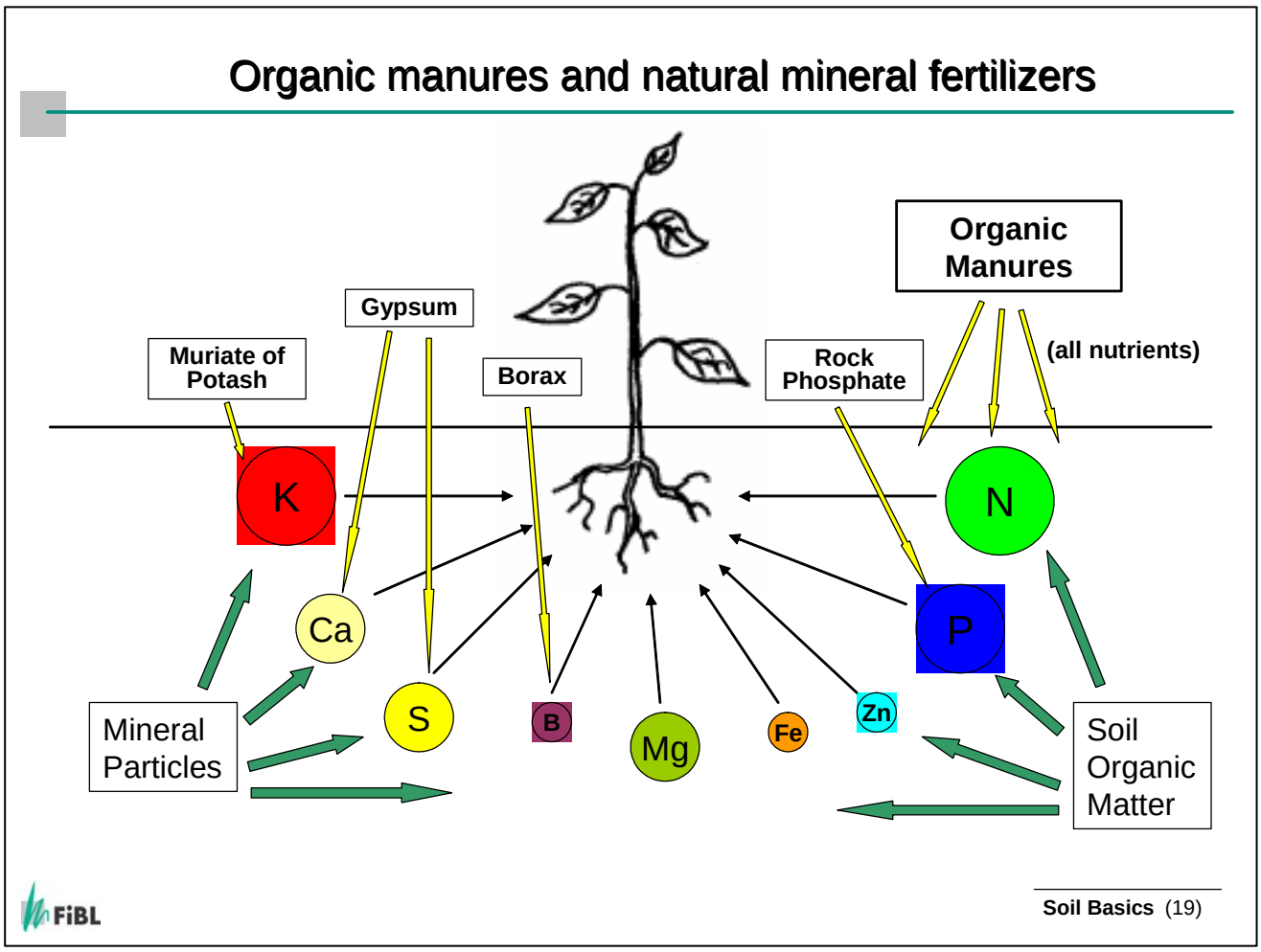
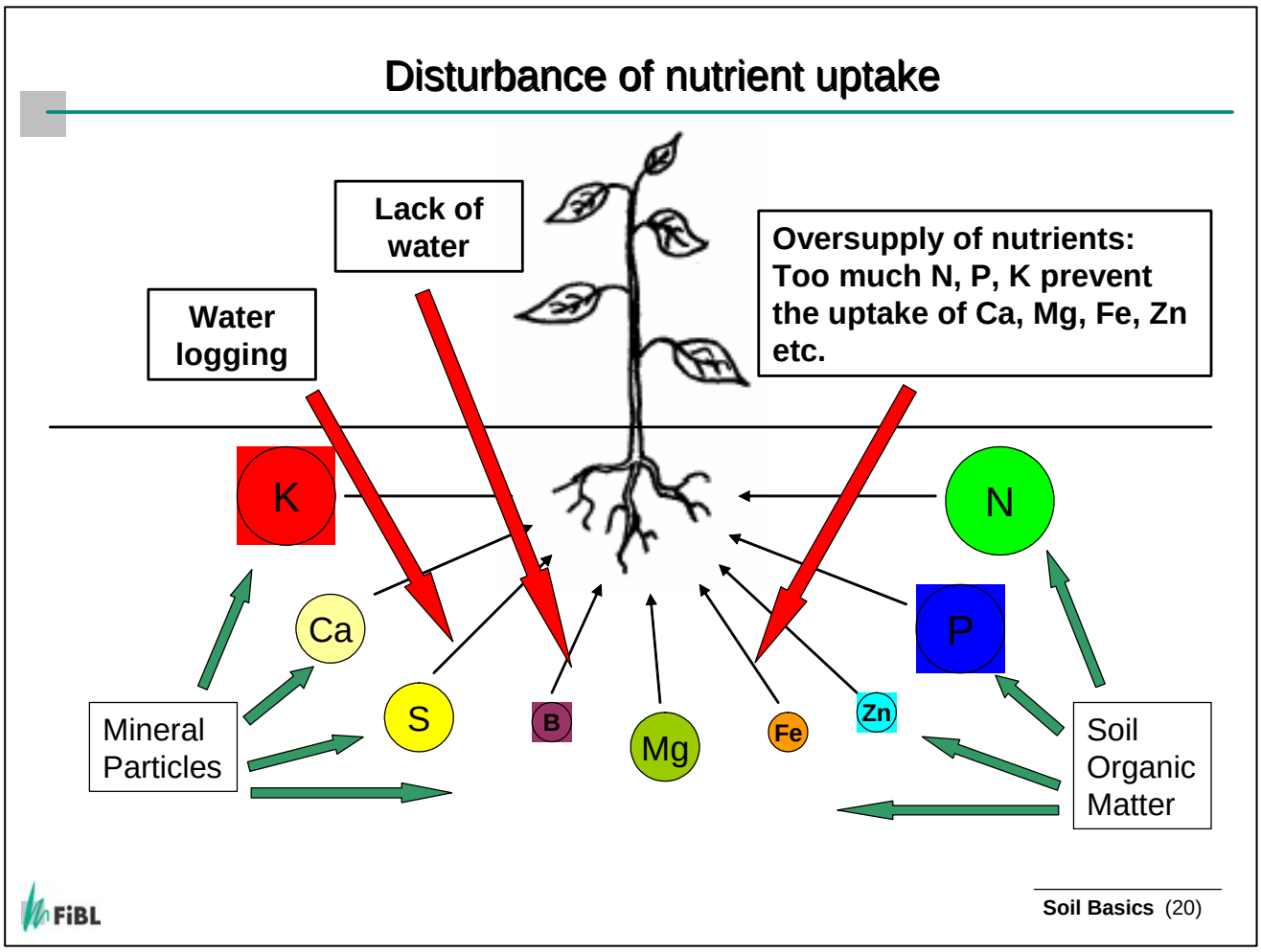
- The table lists a summary of the properties and management recommendations for light and heavy soils prevalent in the Maikaal area.
- The summary needs to be adapted to the respective local situation.



- This and the following two transparencies show how nutrients in the soil are taken up by the plant.
- In the graph nutrients are represented by coloured circles: K = potassium, Ca = Calcium, S = Sulphur, B = Boron, Mg = Magnesia, Fe = Iron, Zn = Zinc, P = Phosphorus, N = Nitrogen
- Left side: Nutrients are released by mineral particles (stone, sand, silt, clay) through weathering and nutrient exchange.
- right side: Nutrients are also released through decomposition of organic matter and through exchange of nutrients bound to organic matter.



- **In organic farming, nutrients can be added through application of organic manures (containing all nutrients) and specific natural mineral fertilizers.**



- **If plants show nutrient deficiency symptoms it does not automatically mean that there are not enough nutrients in the soil.**
- **Nutrient uptake can be hindered through water logging (not enough air in the soil) or lack of water (nutrient uptake always requires water).**
- **Oversupply of some nutrients, especially of N, P and K, can also prevent the uptake of other essential nutrients such as Ca, Mg, Fe and Zn. Thus it is important that not too much manure and fertilizer is applied.**

Nutrient deficiency symptoms in cotton and suitable manures

Nutrient	Deficiency Symptoms	Possible Reasons	Suitable Manures/Fertilizers
Nitrogen (N)	small, pale yellow leaves stunted growth	Few organic matter in the soil; water logging or dryness; presence of straw, immature compost etc.; too much irrigation	Crop rotation with pulses, application of organic manure (e.g. DOC) before flowering
Phosphorus (P)	Stunted plants with dark green leaves, purple spots on leave edges; Pre-mature senescence	Sandy soils; few organic matter content; reduced uptake due to water logging or overcast weather;	Application of compost, manure; application of rock phosphate in compost (50 – 100 kg/ha)
Potassium (K)	Leaf margins and interveinal areas show yellowish white mottling, then rusty bronze colour, then necrotic spots; small immature bolls; poor fibre quality	Sandy soils; high contents of nitrogen, soda, magnesia or calcium	Application of wood ash in compost; application of muriate of potash (50 kg K/ha)
Sulphur (S)	Yellowing of young leaves while old ones remain green; spindly plants with short slender, stem;	Mainly in dry-land crops and sandy soils. Problem of leaching of Sulphate.	Application of gypsum (25 - 50 kg/ha)
Zinc (Zn)	Intervenial chlorosis (yellowing between the leave veins); cupped leaves, bronzing. Short growth.	Poorly soluble in the soil, thus association with VAM improves uptake. Low VAM due to long fallow or dry conditions.	Application of 5-10 kg Zn-Oxide or Zn-Sulphate per ha once in several years
Boron (B)	Young leaves become light green at their base, older leaves become twisted; flowers are malformed; deformed bolls	Mainly in sandy soils, easily leached; alkaline soils. Main supply from organic matter.	Application of 0.5 – 1 kg Borax salt per ha, applied just before sowing. Attention: high application has toxic effects!

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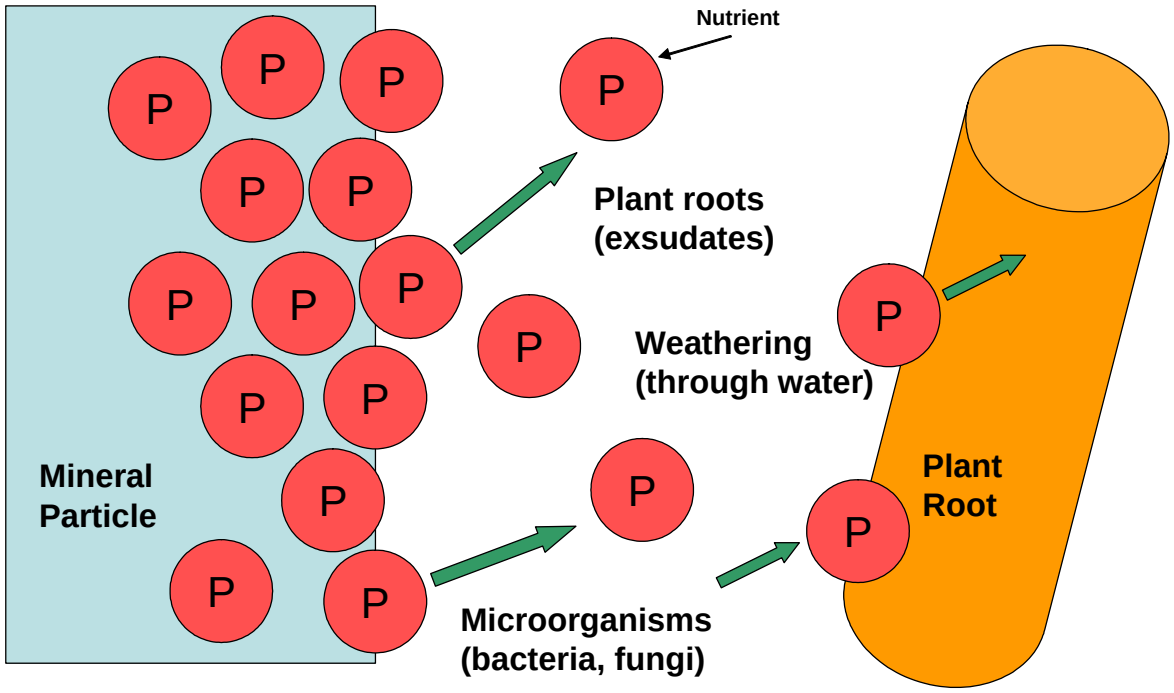
Soil Basics (21)

- **The table lists the nutrient deficiency symptoms in cotton, possible reasons for the symptom (it does not automatically mean that there are not enough nutrients in the soil; see previous transparency!), and suitable manures / fertilizers in case of real nutrient deficiency (get soil tested!).**

Which fraction of a nutrient is available to the plant?



- Not all nutrients present in the soil (in the mineral particles or organic matter) are readily available to the plant root (brown cylinder).
- In the illustration, part of the nutrients (phosphate ions) present in a soil mineral particle are released through weathering and are taken up by the plant root.
- In addition, plant roots can actively dissolve nutrients with the help of substances (exudates) emitted by the root.
- Nutrient release and uptake is also facilitated through micro-organisms.
- Soil tests usually only measure the nutrients that are easily available, but neglect the effect of root exudates and micro-organisms. Thus in organically managed soils, nutrient availability may be actually higher than suggested by soil analysis.

Soil testing: Potential and constraints

Potential for science:

- Relating the yields to the general fertility of the soil (physical properties, texture).
- Comparing the nutrient status of organic and conventional fields.
- Monitoring the organic matter content during conversion.
- Identifying yield influencing parameters.
- Etc.

Potential for cotton farmers:

- Rough estimate on the nutrient status of P, K, Fe and Zn.
- Recommendations on the amount of manures/ mineral fertilizers.

Constraints:

- Only a small part of the nutrients in the soil is available to the crop.
- The extractants for soil nutrient testing are only a rough approximation.
- In organically managed soils, micro-organisms and plant roots usually can extract more nutrients than in conventionally managed soils.
- The nitrogen content can change rapidly with changing weather conditions.
- Soil samples need to consider the variation within the field.
- Costs of sending and analysis.
- Correct interpretation of the results is not easy.

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- The table summarizes the potentials and constraints of soil analysis for science and for farmers.

Organic manures and natural mineral fertilizers for cotton

Manure/Fertilizer	Comment	Nitrogen (total N)	Phosphate (P_2O_5)	Potash (K_2O)
Compost	Soil improvement	0.6 - 1.5 %	0.5 - 1.0 %	0.5 - 2.0 %
Farmyard manure	Less stable humus	0.7 - 1.5 %	0.5 - 0.9 %	0.4 - 1.5 %
Vermi-compost	Very stable humus	0.6 - 1.5 %	0.4 - 0.9 %	0.5 - 1.0 %
De-oiled Castor	N- and P-supply	4.5 - 6.0 %	0.8 - 1.8 %	1.3 - 1.5 %
Cane press mud	Soil improvement	1.4 - 1.8 %	0.1 – 1.0 %	0.4 - 0.6 %
Rock phosphate	P-supply, in compost heap	0	15 - 30 %	0
Muriate of potash	Natural potassium fertilizer	0	0	ca. 60 %
Wood ash	K, Mg, Ca, Mg etc.	0	1 - 3 %	1 – 8 %

Note: Figures are given in percent of dry matter. The nutrient contents vary from source to source.

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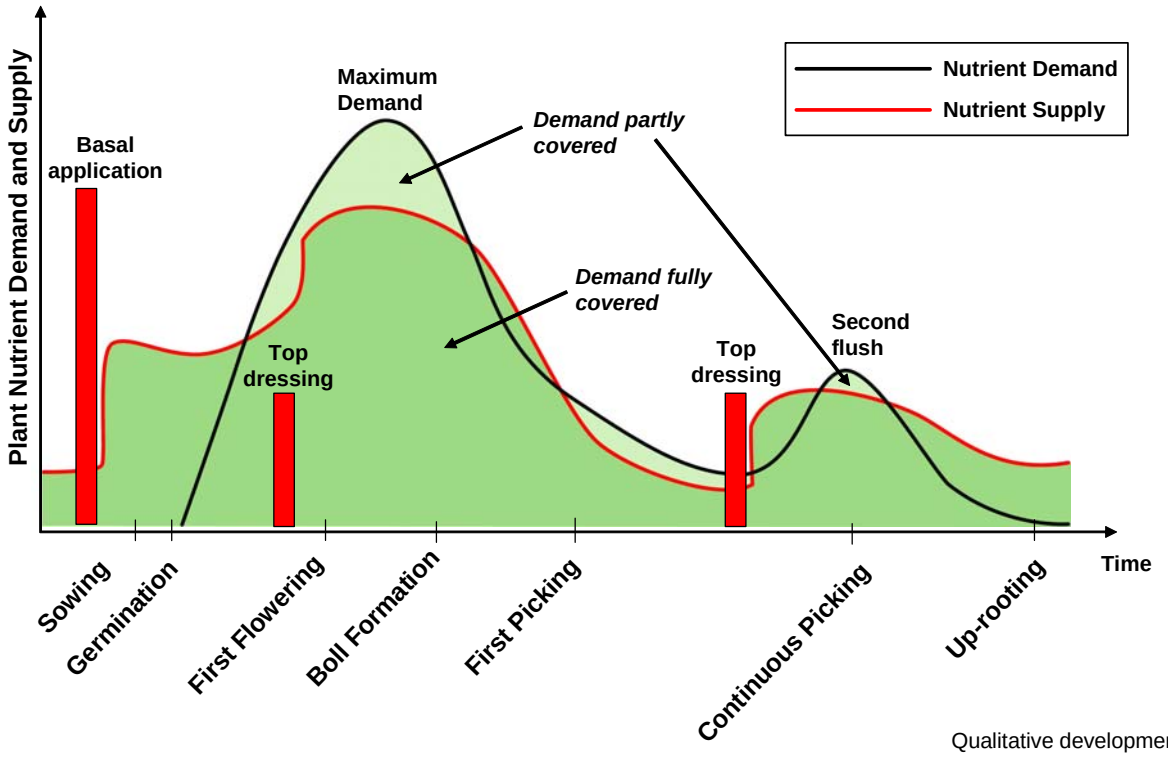
- **Approximate nutrient contents (N = Nitrogen, as total N, P = Phosphorus, as Phosphate, K = potassium, as potassium oxide) of selected organic manures and natural mineral fertilizers typically used in organic cotton.**
- **The nutrient contents strongly vary from source to source. This is especially true for organic manures (composts, FYM, oil cakes etc.).**

Timing of nutrient supply in the cotton crop



Qualitative development, not accurate

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Soil Basics (25)

- **Nutrients should be supplied in a way that they meet the demand of the plant. For this, timing of manure application is important.**
- **The black curve shows the approximate nutrient demand of a cotton plant in its different life stages.**
- **Organic manures need time to decompose and thus to release nutrients (indicated by arrows). Thus, they should be applied 1-3 weeks earlier than chemical fertilizers in conventional farming.**
- **However, in organic farming most important is the overall soil fertility, established through good crop rotation and basal application of compost and FYM.**

Nitrogen fixation through leguminous plants

- There is plenty of Nitrogen in the air (78% Nitrogen-Gas)
- Leguminous plants fix Nitrogen from the air and make it available to the plant
- Examples: pigeon pea, soya bean, moong, cow pea, chick pea, daal etc.
- The fixation happens through bacteria living in root nodules (Rhizobium species)
- The nitrogen fixed by the leguminous crop gets available to the associated or following crop (e.g. cotton)
- If a lot of fertilizer is available in the soil, legumes fix less nitrogen

- The photo shows root nodules on a leguminous crop (vetch).
- The text summarizes important points related to nitrogen fixation.

Nitrogen immobilisation in soil → retarded growth

Symptoms

- Yellowish leaves
- Stunted growth
- Delayed development

The reason

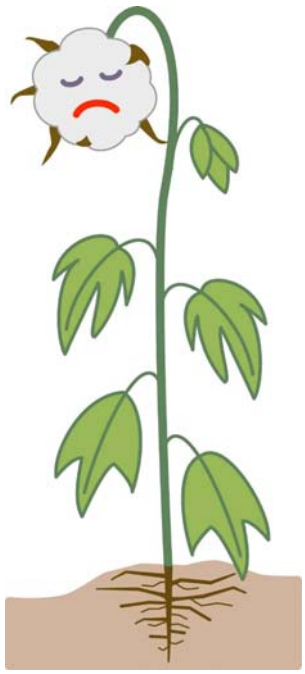
Decomposable material in the soil (half rotten compost or manure, straw, crop residues)

↓

The decomposition of carbon-rich organic material requires nitrogen

↓

Little organic material with high nitrogen content (e.g. oil cake)



Preventive measures

- Remove sturdy crop residues (stalks) from the field and compost them
- Ensure that the compost is well decomposed
- Apply compost at least two weeks before sowing
- Apply sufficient nitrogen-rich organic manures (e.g. de-oiled cakes)
- Note: Organic manures need 1-3 weeks until they release nitrogen
- Shallow soil cultivation helps to accelerate decomposition of organic matter

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Soil Basics (27)

- Nitrogen immobilisation occurs when organic material with low nitrogen content (e.g. straw, crop residues) starts decomposing.
- The microbes involved in the decomposition require nitrogen, which the effectively acquire from the soil. Thus the y compete with the crop.
- The nitrogen is not lost but only temporarily not available. It will be released again once the decomposition proceeds.
- Symptoms, reasons and measures how to avoid nitrogen immobilisation are given in the text.