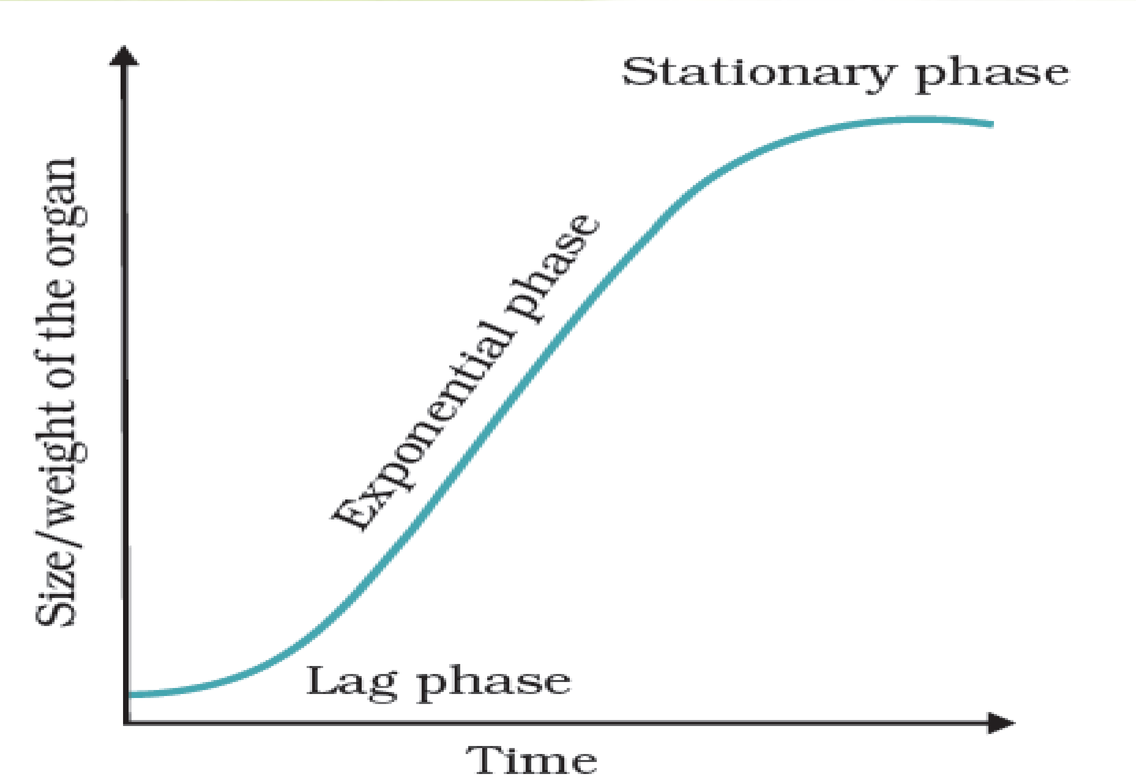
2.PERTUMBUHAN DAN FAKTOR-FAKTOR YANG MEMPENGARUHINYA



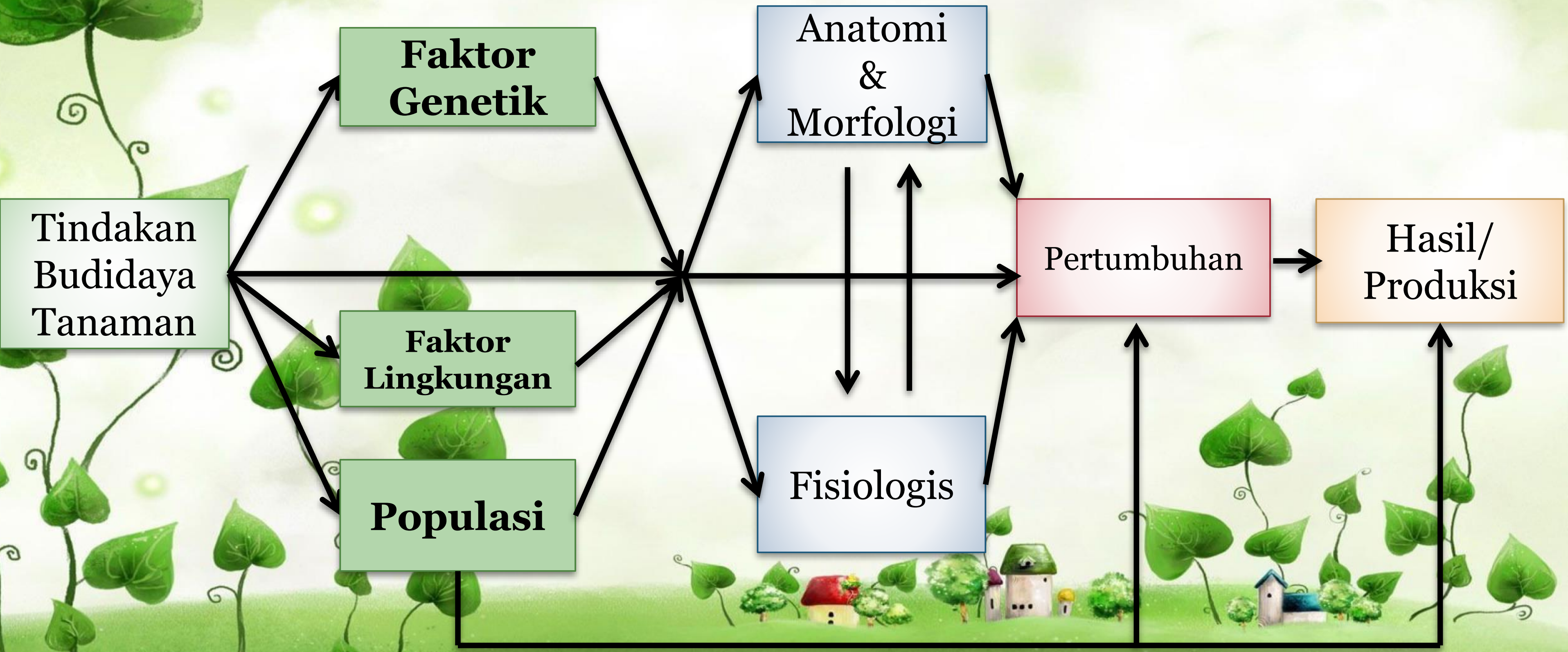
KURVA PERTUMBUHAN FUNGSI WAKTU

MEASURING GROWTH

- Fresh weight
- Dry weight
- Volume
- Length
- Height
- Surface area

MEASURING GROWTH

- Definition:
  - Size increase by cell division and enlargement, including synthesis of new cellular material and organization of subcellular organelles.


Tindakan Budidaya Tanaman
Faktor Genetik
Faktor Lingkungan
Populasi
Anatomi & Morfologi
Fisiologis
Pertumbuhan
Hasil/ Produksi

Faktor yang mempengaruhi pertumbuhan dan produksi tanaman

Faktor internal

Faktor Eksternal

Iklim :
1. Radiasi Mth
2. Suhu
3. Kelembaban
4. Angin

Edafik (Tanah) :
1. Sifat Fisika
2. Sifat Kimia
3. Sifat Biologi

OPT :
1. Hama
2. Penyakit
3. Gulma

SOSEK :
1. Pengetahuan
2. Pendapatan
3. dll

I. Internal factors

Genetic factors

The increase in crop yields and other desirable characters are related to Genetic make up of plants.

- High yielding ability
- Early maturity
- Resistance to lodging
- Drought flood and salinity tolerance
- Tolerance to insect pests and diseases
- Chemical composition of grains (oil content, protein content)
- Quality of grains (fineness, coarseness)
- Quality of straw (sweetness, juiciness)

The above characters are less influenced by environmental factors since they are governed by genetic make-up of crop.

GENETIC FACTORS AFFECTING GROWTH AND DEVELOPMENT

- DNA directs growth and differentiation
  - Enzymes catalyze biochemical reactions
- Structural genes
  - Genes involved in protein synthesis
- Operator genes
  - Regulate structural genes
- Regulatory genes
  - Regulate operator genes

2. External factors

A. Climatic
B. Edaphic
C. Biotic
D. Phsiographic
E. Socio-economic

A. CLIMATIC FACTORS

Nearly 50 % of yield is attributed to the influence of climatic factors.The following are the atmospheric weather variables which influences the crop production.

1. Precipitation
2. Temperature
3. Atmospheric humidity
4. Solar radiation
5. Wind velocity
6. Atmospheric gases

1. Precipitation

- Precipitation includes all water which falls from atmosphere such as rainfall, snow, hail, fog and dew.
- Rainfall one of the most important factor influences the vegetation of a place.
- Total precipitation in amount and distribution greatly affects the choice of a cultivated species in a place.

- In heavy and evenly distributed rainfall areas, crops like rice in plains and tea, coffee and rubber in Western Ghats are grown.
- Low and uneven distribution of rainfall is common in dryland farming where drought resistance crops like pearl millet, sorghum and minor millets are grown.
- In desert areas grasses and shrubs are common where hot desert climate exists
- Though the rainfall has major influence on yield of crops, yields are not always directly proportional to the amount of Precipitation as excess above optimum reduces the yields
- Distribution of rainfall is more important than total rainfall to have longer growing period especially in drylands

2. Temperature

- Temperature is a measure of intensity of heat energy. The range of temperature for maximum growth of most of the agricultural plants is between 15 and 40ºC.
- The temperature of a place is largely determined by its distance from the equator (latitude) and altitude.
- It influences distribution of crop plants and vegetation.
- Germination, growth and development of crops are highly influenced by temperature.
- Affects leaf production, expansion and flowering.
- Physical and chemical processes within the plants are governed by air temperature.
- Diffusion rates of gases and liquids changes with temperature.
- Solubility of different substances in plant is dependent on temperature.
- The minimum, maximum (above which crop growth ceases) and optimum temperature of individual's plant is called as cardinal temperature.

Crops	Minimum temperature ºC	Optimum temperature ºC	Maximum temperature ºC
Rice	10	32	36-38
wheat	4.5	20	30-32
Maize	8-10	20	40-43
Sorghum	12-13	25	40
Tobacco	12-14	29	35

3. Atmospheric Humidity (Relative Humidity - RH)

- Water is present in the atmosphere in the form of invisible water vapour, normally known as humidity. Relative humidity is ratio between the amount of moisture present in the air to the saturation capacity of the air at a particular temperature.
- If relative humidity is 100% it means that the entire space is filled with water and there is no soil evaporation and plant transpiration.
- Relative humidity influences the water requirement of crops
- Relative humidity of 40-60% is suitable for most of the crop plants.
- Very few crops can perform well when relative humidity is 80% and above.
- When relative humidity is high there is chance for the outbreak of pest and disease.

ENVIRONMENTAL FACTORS INFLUENCING PLANT GROWTH

- Water
  - most growing plants contain about 90% water
  - amount needed for growth varies with plant and light intensity
  - transpiration drives water uptake from soil
    - water pulled through xylem
    - exits via stomates
  - **evapotranspiration** - total loss of water from soil
    - loss from soil evaporation and plant transpiration

4. Solar radiation (without which life will not exist)

- From germination to harvest and even post harvest crops are affected by solar radiation.
- Biomass production by photosynthetic processes requires light.
- All physical process taking place in the soil, plant and environment are dependent on light
- Solar radiation controls distribution of temperature and there by distribution of crops in a region.
- Visible radiation is very important in photosynthetic mechanism of plants. Photosynthetically Active Radiation (PAR - 0.4 – 0.7μ) is essential for production of carbohydrates and ultimately biomass.

  0.4 to 0.5 μ - Blue – violet – Active
  0.5 to 0.6 μ - Orange – red - Active
  0.5 to 0.6 μ - Green –yellow – low active

- Photoperiodism is a response of plant to day length

  Short day – Day length is <12 hours (Rice, Sunflower and cotton), long day – Day length is > 12 hours (Barley, oat, carrot and cabbage), day neutral – There is no or less influence on day length (Tomato and maize).

- Phototropism — Response of plants to light direction. Eg. Sunflower
- Photosensitive – Season bound varieties depends on quantity of light received

5. Wind velocity

- The basic function of wind is to carry moisture (precipitation) and heat.
- The moving wind not only supplies moisture and heat, also supplies fresh CO_2 for the photosynthesis.
- Wind movement for 4 – 6 km/hour is suitable for more crops.
- When wind speed is enormous then there is mechanical damage of the crops (i.e.) it removes leaves and twigs and damages crops like banana, sugarcane
- Wind dispersal of pollen and seeds is natural and necessary for certain crops.
- Causes soil erosion.
- Helps in cleaning produce to farmers.
- Increases evaporation.
- Spread of pest and diseases.

6. Atmospheric gases on plant growth

- CO_2 – 0.03%, O_2 - 20.95%, N_2 - 78.09%, Argon - 0.93%, Others - 0.02%.
- CO_2 is important for Photosynthesis, CO_2 taken by the plants by diffusion process from leaves through stomata
- CO_2 is returned to atmosphere during decomposition of organic materials, all farm wastes and by respiration
- O_2 is important for respiration of both plants and animals while it is released by plants during Photosynthesis
- Nitrogen is one of the important major plant nutrient, Atmospheric N is fixed in the soil by lightning, rainfall and N fixing microbes in pulses crops and available to plants
- Certain gases like SO_2, CO, CH_4, HF released to atmosphere are toxic to plants

B. EDAPHIC FACTORS (soil)

Plants grown in land completely depend on soil on which they grow. The soil factors that affect crop growth are

1. Soil moisture
2. Soil air
3. Soil temperature
4. Soil mineral matter
5. Soil organic matter
6. Soil organisms
7. Soil reactions

1. Soil moisture

- Water is a principal constituent of growing plant which it extracts from soil
- Water is essential for photosynthesis
- The moisture range between field capacity and permanent wilting point is available to plants.
- Available moisture will be more in clay soil than sandy soil
- Soil water helps in chemical and biological activities of soil including mineralization
- It influences the soil environment Eg. it moderates the soil temperature from extremes
- Nutrient availability and mobility increases with increase in soil moisture content.

2. Soil air

- Aeration of soil is absolutely essential for the absorption of water by roots
- Germination is inhibited in the absence of oxygen
- O_2 is required for respiration of roots and micro organisms.
- Soil air is essential for nutrient availability of the soil by breaking down insoluble mineral to soluble salts
- For proper decomposition of organic matter
- Potato, tobacco, cotton linseed, tea and legumes need higher O_2 in soil air
- Rice requires low level of O_2 and can tolerate water logged (absence of O2) condition.

3. Soil temperature

- It affects the physical and chemical processes going on in the soil.
- It influences the rate of absorption of water and solutes (nutrients)
- It affects the germination of seeds and growth rate of underground portions of the crops like tapioca, sweet potato.
- Soil temperature controls the microbial activity and processes involved in the nutrient availability
- Cold soils are not conducive for rapid growth of most of agricultural crops

4. Soil mineral matter

- The mineral content of soil is derived from the weathering of rocks and minerals as particles of different sizes.
- These are the sources of plant nutrients

  eg; Ca, Mg, S, Mn, Fe, K etc

5. Soil Organic matter

- It supplies all the major, minor and micro nutrients to crops
- It improves the texture of the soil
- It increases the water holding capacity of the soil,
- It is a source of food for most microorganisms
- Organic acids released during decomposition of organic matter enables mineralisation process thus releasing unavailable plant nutrients

6. Soil organisms:

- The raw organic matter in the soil is decomposed by different micro organisms which in turn releases the plant nutrients
- Atmospheric nitrogen is fixed by microbes in the soil and is available to crop plants through symbiotic (*Rhizobium*) or non-symbiotic (*Azospirillum*) association

7. Soil reaction (pH)

- Soil reaction is the pH (hydrogen ion concentration) of the soil.
- Soil pH affects crop growth and neutral soils with pH 7.0 are best for growth of most of the crops
- Soils may be acidic (<7.0), neutral (=7.0), saline and alkaline (>7.0)
- Soils with low pH is injurious to plants due high toxicity of Fe and Al.
- Low pH also interferes with availability of other plant nutrients.

D. Physiographic factors:

- Topography is the nature of surface earth (leveled or sloppy) is known as topography. Topographic factors affect the crop growth indirectly.
- Altitude – increase in altitude cause a decrease in temperature and increase in precipitation and wind velocity (hills and plains)
- Steepness of slope: it results in run off of rain water and loss of nutrient rich top soil
- Exposure to light and wind: a mountain slope exposed to low intensity of light and strong dry winds may results in poor crop yields (coastal areas and interior pockets)

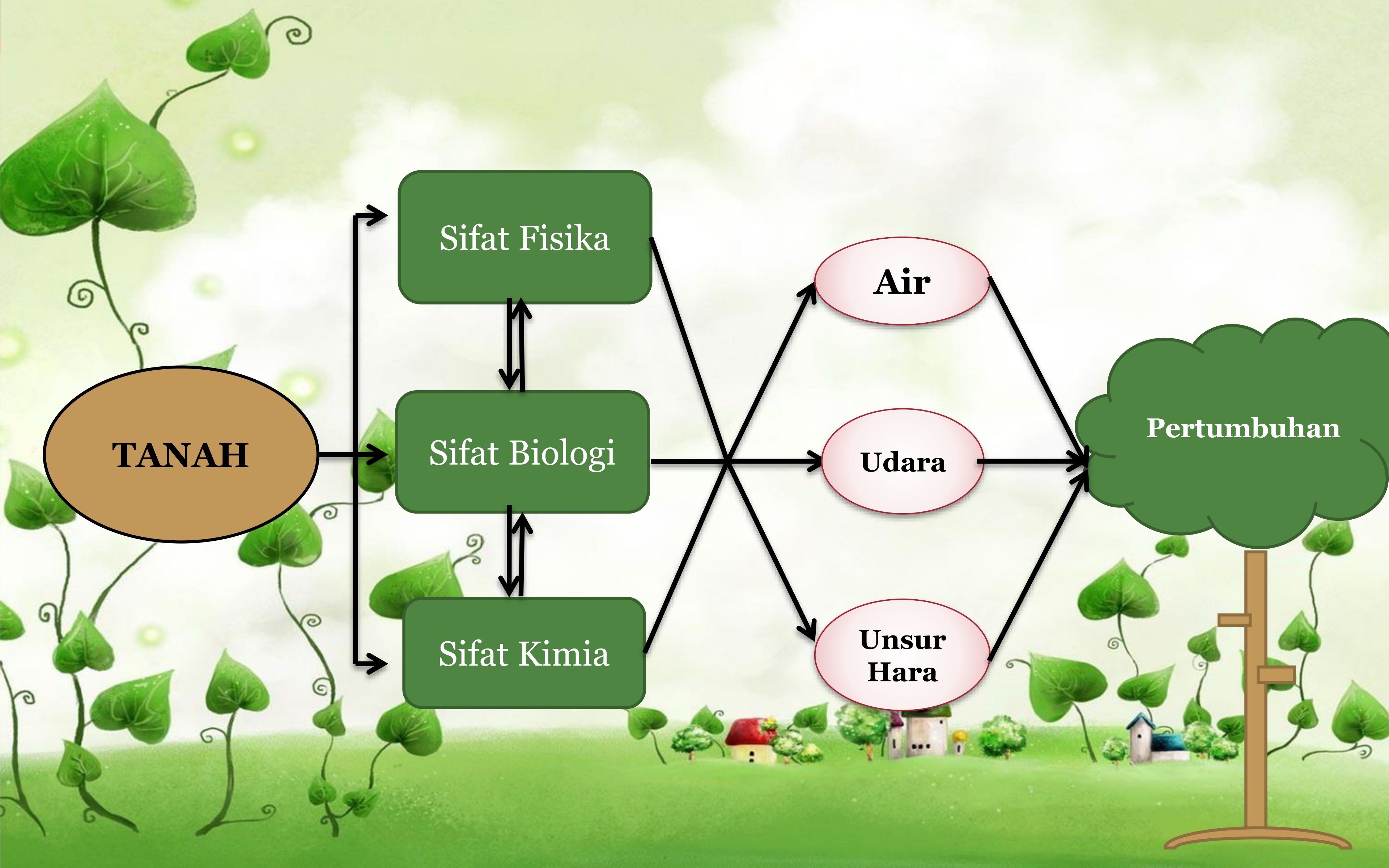
E. Socio-economic factors

- Society inclination to farming and members available for cultivation
- Appropriate choice of crops by human beings to satisfy the food and fodder requirement of farm household.
- Breeding varieties by human invention for increased yield or pest & disease resistance
- The economic condition of the farmers greatly decides the input/ resource mobilizing ability (marginal, small, medium and large farmers)

C. FAKTOR BIOTIK

- Organisme Pengganggu Tanaman

  1. Hama
  2. Penyakit
  3. Gulma


TANAH
Sifat Fisika
Sifat Biologi
Sifat Kimia
Air
Udara
Unsur Hara
Pertumbuhan

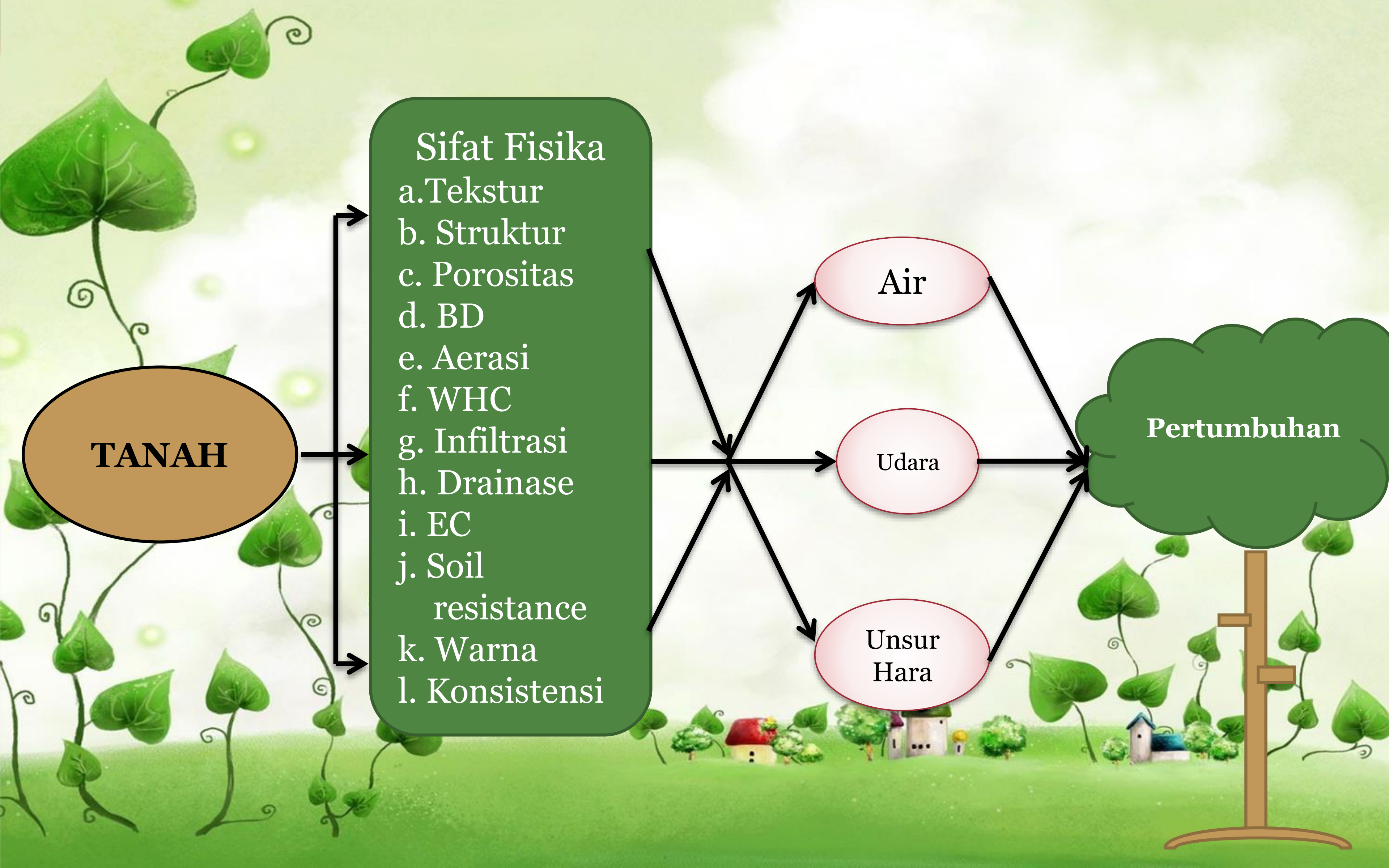

TANAH
Sifat Fisika
a.Tekstur
b. Struktur
c. Porositas
d. BD
e. Aerasi
f. WHC
g. Infiltrasi
h. Drainase
i. EC
j. Soil resistance
k. Warna
l. Konsistensi
Air
Udara
Unsur Hara
Pertumbuhan

Table 3.1. Pore size distribution in soils different in texture (Scheffer et al., 1989).

Soils different in texture 3	Pore volume [%]	Macropores [%]	Medium-sized pores [%]	Micropores [%]
Sandy soils	46 (+/- 10)	30 (+/- 10)	7 (+/- 5)	5 (+/- 3)
Silty soils	47 (+/- 9)	15 (+/- 10)	15 (+/- 7)	15 (+/- 5)
Clayey soils	50 (+/- 15)	8 (+/- 5)	10 (+/- 5)	35 (+/- 10)
Organic soils	85 (+/- 10)	25 (+/- 10)	40 (+/- 10)	25 (+/- 10)

Generalized Influence of Soil Separates on Some Properties and Behavior of Soils.[a]

Property/behavior	Rating associated with soil separates		
	Sand	*Silt*	*Clay*
Water-holding capacity	Low	Medium to high	High
Aeration	Good	Medium	Poor
Drainage rate	High	Slow to medium	Very slow
Soil organic matter level	Low	Medium to high	High to medium
Decomposition of organic matter	Rapid	Medium	Slow
Warm-up in spring	Rapid	Moderate	Slow
Compactability	Low	Medium	High
Susceptibility to wind erosion	Moderate (high if fine sand)	High	Low
Susceptibility to water erosion	Low (unless fine sand)	High	Low if aggregated, high if not
Shrink-swell potential	Very Low	Low	Moderate to very high
Sealing of ponds, dams, and landfills	Poor	Poor	Good
Suitability for tillage after rain	Good	Medium	Poor
Pollutant leaching potential	High	Medium	Low (unless cracked)
Ability to store plant nutrients	Poor	Medium to high	High
Resistance to pH change	Low	Medium	High

[a] Exceptions to these generalizations do occur, especially as a result of soil structure and clay mineralogy.

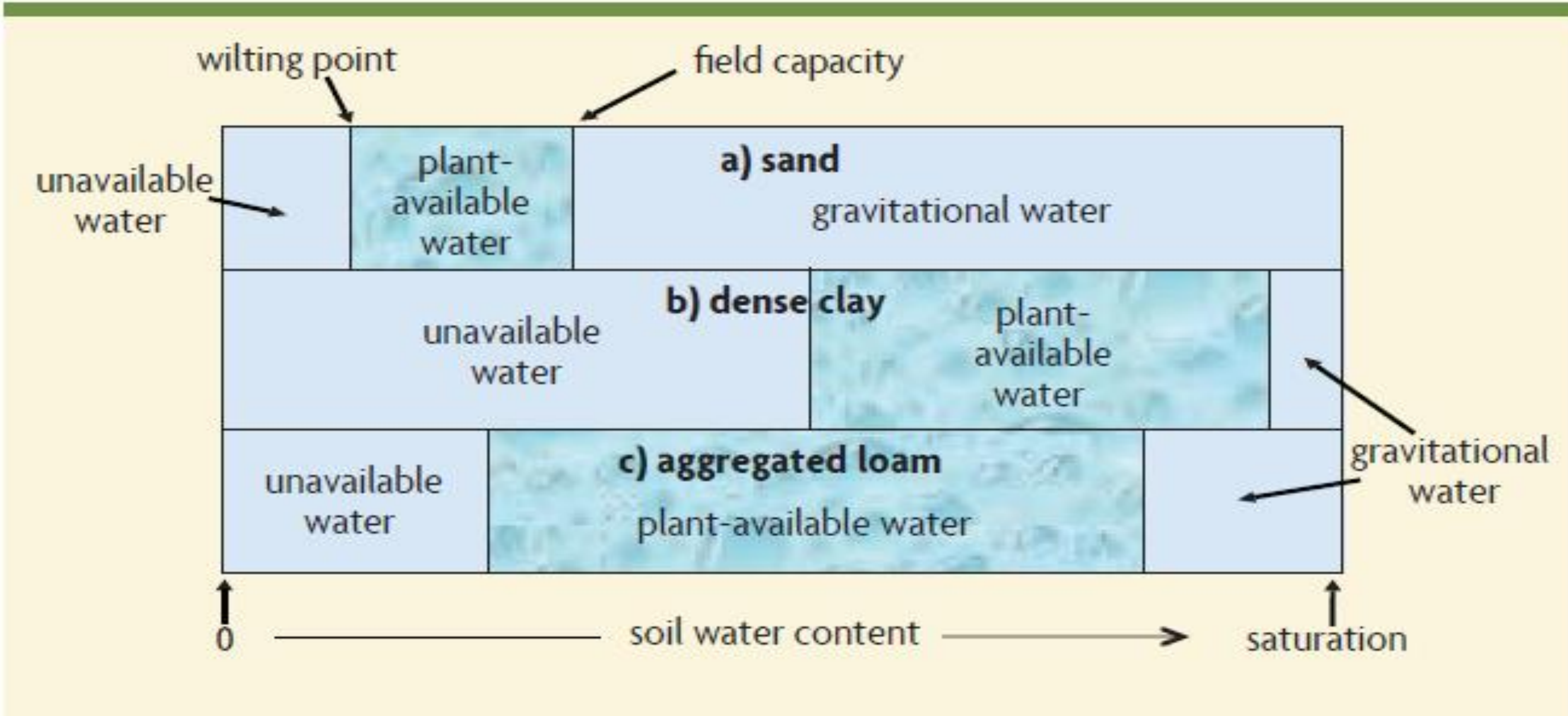


Figure 5.4. Water storage for three soils.

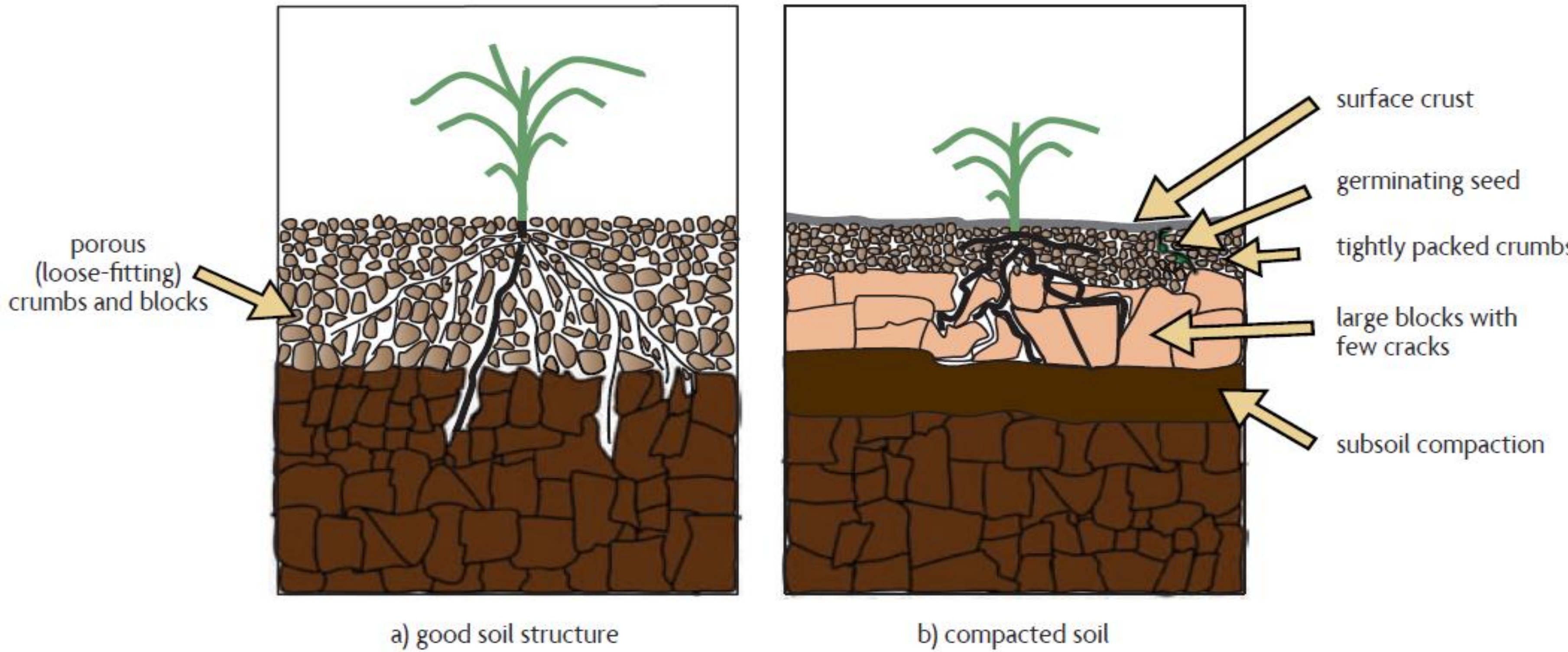


Figure 6.6. Plants growing in (a) soil with good tilth and (b) soil with all three types of compaction.

5. Tata Udara Tanah (Aerasi Tanah)

4). Kepentingan aerasi tanah:

Dalam penyediaan Oksigen, yg penting dalam:

a. Respirasi akar tanaman, shg mempengaruhi serapan hara dan air. Dg cara dmk mempengaruhi pertumbuhan tanaman.

a. Respirasi organisme tanah, yang berpengaruh thd kesuburan tanah.

6. Suhu Tanah

a. Pengaruh suhu thd tanah dan tanaman

Suhu tnh berpengaruh thd aktivitas organisme tanah. Penurunan suhu tanah menyebabkan penurunan aktivitas organisme tanah, yg berefek pd penyediaan hara, dan sifat fisik tanah (Kesuburan tanah).

6. Suhu Tanah

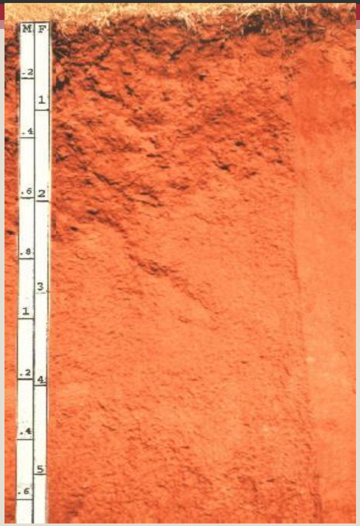
Suhu juga berefek pd evaporasi dan transpirasi, yg berefek pd penyediaan air, serapan air dan hara, dan pertumbuhan tanaman.

Pengaruh suhu thd tanaman scr tdk langsung efeknya thd tanah, dan efek langsung terhadap metabolisme tanaman termasuk respirasi akar. Respirasi akar berefek pd penyerapan hara dan air, yg selanjutnya berefek pd metabolisme tanaman lainnya.

Beberapa Arti Warna Tanah

1. Menunjukkan kandungan bahan organik.
   a. Warna tanah gelap menunjukkan kandungan bahan organik tinggi.
   b.Dekomposisi bahan organik menghasilkan humus yang stabil berwarna lebih gelap.

2. Menunjukkan kondisi drainase tanah
   a. Drainase tanah yang baik dicirikan dengan warna tanah merah sedangkan drainase yang buruk ditunjukkan dengan warna tanah kelabu.
   b. Okdidasi besi menghasilkan warna merah dan reduksi besi menghasilkan warna kelabu.






3. Menunjukkan Adanya Senyawa Tertentu

Gelap : Besi + humus
Karbon sebagai unsur
Mn, magnetit

Merah : Besi oksida anhidrat (relatif tidak stabil dalam kondisi lembab)
Drainase + aerasi baik
Topografi cembung (permukaan)
Bila bahan induk stabil
Hancuran iklim intensif

Coklat : Variasi bahan organik + oksida besi

Kuning: Besi oksida
Iklim tanah lebih lembab daripada warna merah

	kelembaban	site	awan	geologi
Kuning	lebih tinggi	kurang cembung	berat	pengangkatan baru
Merah	lebih rendah	cembung	kurang	tua

c. Kepentingan Warna Tanah

- Warna tanah menunjukkan sifat2 tanah.
- Sifat tanah yg berkaitan dengan warna tanah is kandungan bahan organik, kondisi drainase dan aerasi.
- Warna tanah juga digunakan untuk mencirikan perbedaan horison2 tanah.
- Warna tanah juga digunakan dalam klasifikasi tanah

8. Water Holding Capacity

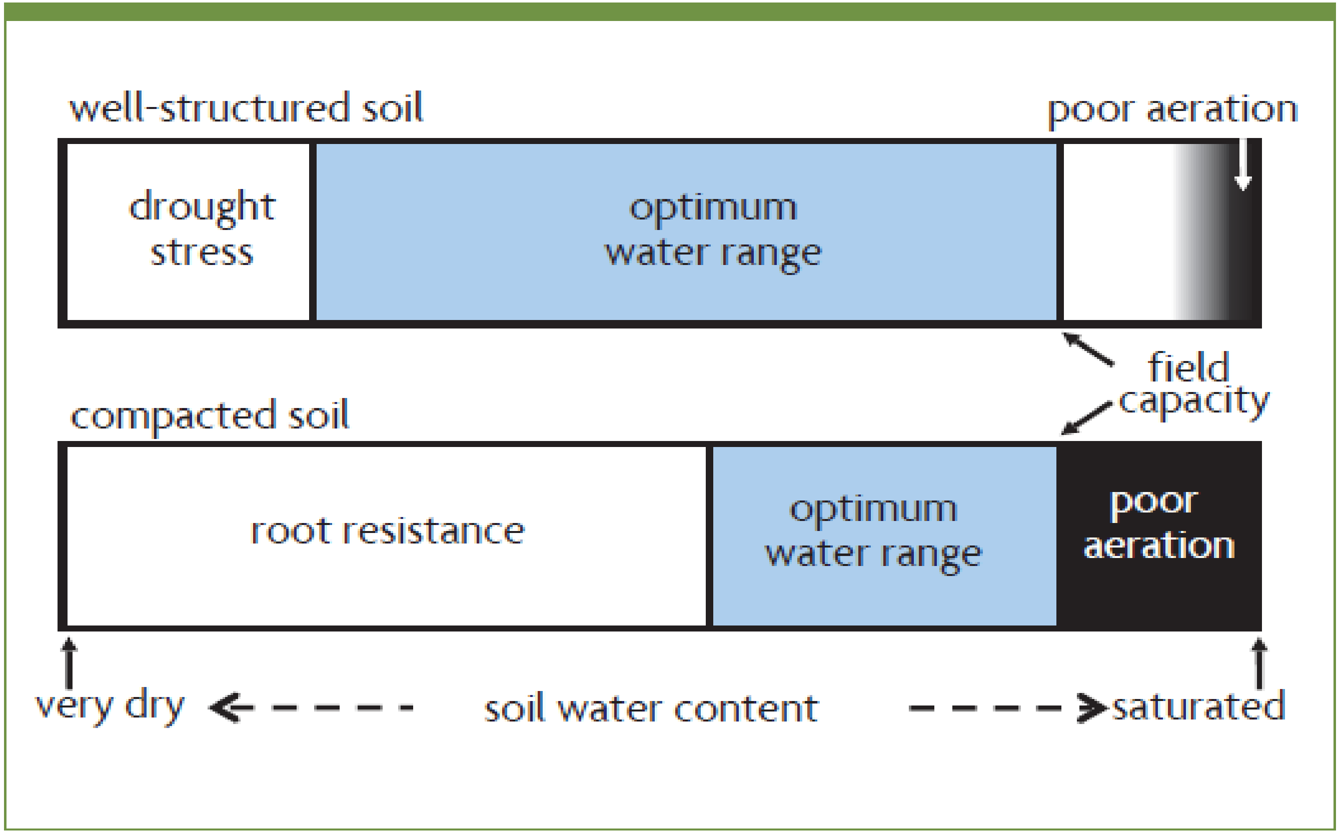


Figure 6.12. The optimum water range for crop growth for two different soils.

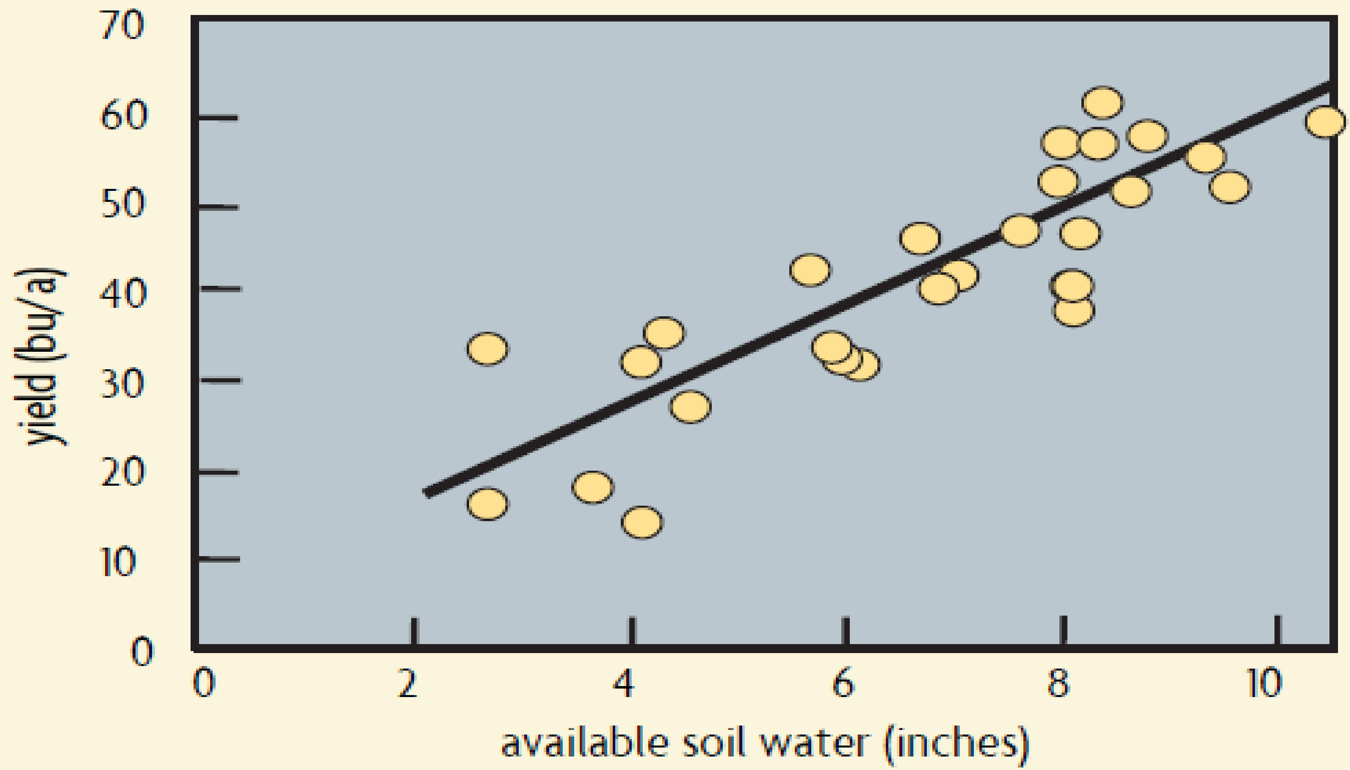
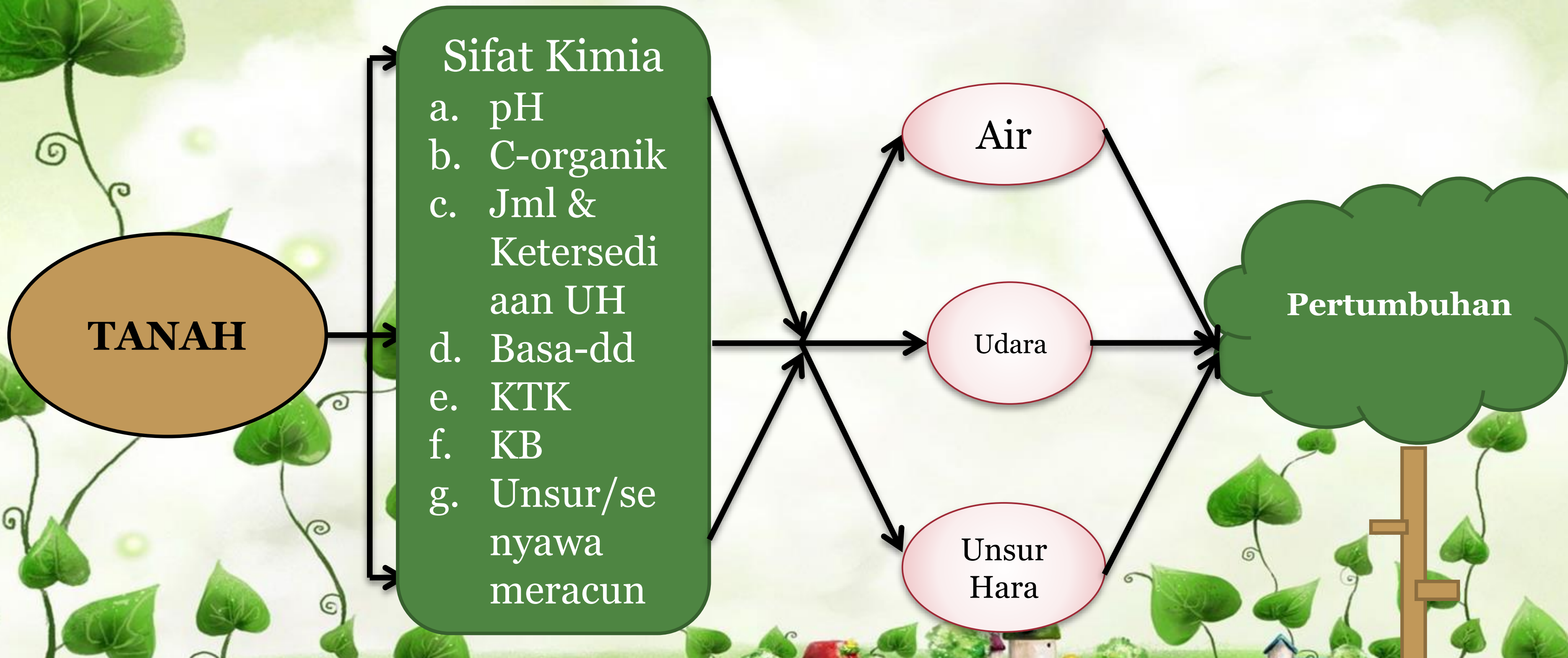
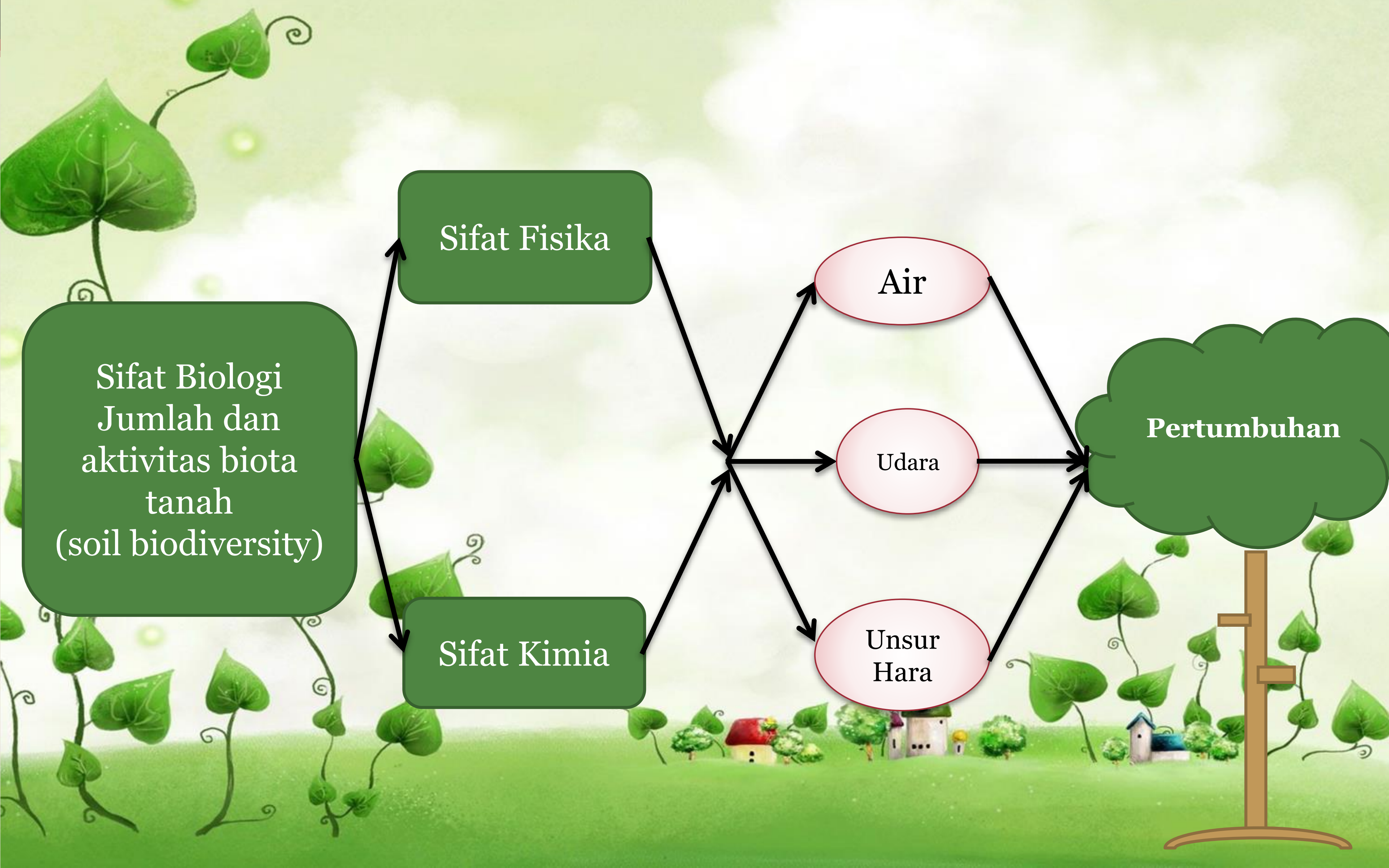


Figure 9.1. Relationship between winter wheat grain yield and soil water at wheat planting over six years. Modified from Nielsen et al. (2002).


TANAH
Sifat Kimia
a. pH
b. C-organik
c. Jml & Ketersediaan UH
d. Basa-dd
e. KTK
f. KB
g. Unsur/senyawa meracun
Air
Udara
Unsur Hara
Pertumbuhan


Sifat Biologi
Jumlah dan
aktivitas biota
tanah
(soil biodiversity)
Sifat Fisika
Sifat Kimia
Air
Udara
Unsur
Hara
Pertumbuhan

2. FAUNAL INFLUENCES ON SOIL PHYSICAL PROPERTIES

Activities of soil fauna that significantly affect soil structure result from the following (Lee and Foster 1991):

- burrowing and excavation in search of food, or for construction of living spaces or storage chambers within the soil or above the soil surface (e.g. earthworms, termites, ants)
- active transport of excavated or ingested soil which is deposited elsewhere (e.g. ants, earthworms)
- ingestion of soil materials (e.g. earthworms, termites)
- production of faecal pellets (e.g. microarthropods)
- use of excreta, mucus, or salivary secretions to line burrows/galleries or for gluing materials (e.g. termites, earthworms)
- collection of plant litter, animal dung, carrion from the soil surface and incorporating this into the soil with or without prior digestion (e.g. earthworms, dungbeetles).

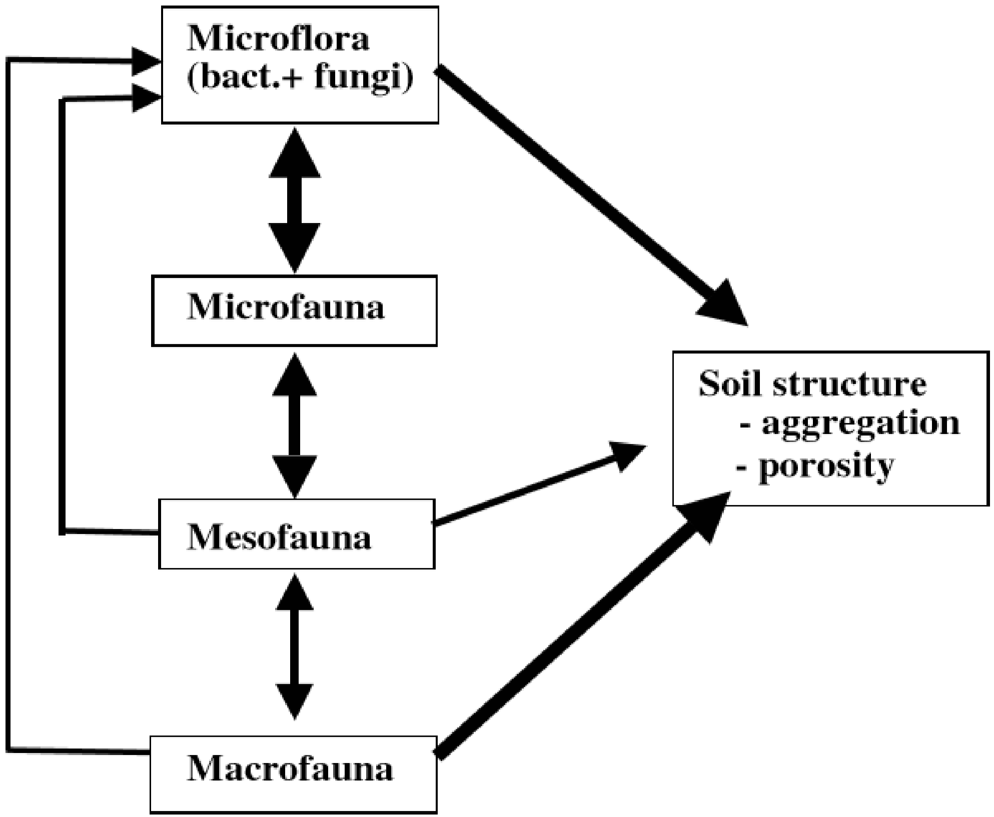


Figure 1 Direct and indirect influences of microflora, microfauna, mesofauna and macrofauna on soil structure. The magnitude of the influence is indicated by the thickness of the solid line between the boxes. Bact = bacteria

2.1 Organisms which affect Soil Structure Through the Production of Faecal Pellets

Animal groups whose contribution to the formation of soil structure is limited to the production of faecal pellets are discussed. These animals hardly ingest any mineral particles and move through the soil using existing pores/burrows, thereby mixing organic matter into the topsoil. Their faecal pellets (microaggregates) may, in turn, serve as building blocks for macroaggregates (Tisdall and Oades 1982).

Pengaruh Fauna Tanah Terhadap Struktur Tanah

- Fauna tanah seperti cacing tanah menghasilkan lendir yang dapat berperan sebagai perekat dalam pembentukan agregat.

Pengaruh Fauna Tanah Terhadap Porositas Tanah

- Secara umum, aktivitas fauna tanah menghasilkan biochannel/biophore
- Cacing tanah, rayap, centipeda, milipeda di dalam tanah membuat saluran (channel) yang dapat meningkatkan porositas tanah.

The impact of soil fauna on soil structure development and stabilisation depends on the spatial and temporal scale of its actions. The following characteristics are therefore important:

- the lifetime of the individual organisms,
- the population density,
- the spatial distribution (local and regional) of the population,
- the length of time that the population has been present at the site,
- the durability of the structures in the absence of the original 'ecosystem engineers',
- the number of attributes of the ecosystem changed through the activities of the engineer (Lawton and Jones 1995).

Pengaruh Mikroba Tanah Terhadap Transformasi kimia di dalam Tanah

Table 1 Key microbial processes mediating chemical transformations associated with nutrient cycling in soil.

Microbial process	Examples of microbial groups involved
Supply of nutrients	
Mineralisation of organic matter	Heterotrophic microorganisms
Solubilisation of minerals	*Penicillium* sp., *Pseudomonas* sp., *Bacillus* sp.
Nutrient transformations	
Methane (CH_4) oxidation	*Methylococcus* sp., *Methylobacter* sp.
Nitrification	
NH_3 to NO_2^-	*Nitrosospira* sp. and *Nitrosomonas* sp.
NO_2^- to NO_3^-	*Nitrobacter* sp.
Non-symbiotic N_2 fixation	*Azospirillum* sp., *Azotobacter* sp.
Symbiotic N_2 fixation	*Rhizobium* sp., *Anabeana* sp.
Sulphur oxidation	*Thiobacillus* sp., Heterotrophic microorganisms
Loss of nutrients	
CO_2 production	Heterotrophic microorganisms
Methane (CH_4) production	*Methanobacterium* sp., *Methanosarcina* sp.
Denitrification (N_2, N_2O)	*Bacillus* sp., *Pseudomonas* sp., *Agrobacterium* sp.
Reduction of SO_4^{2-} to H_2S	*Desulfovibrio* sp., *Desulfomonas* sp.

Pengaruh Mikroba Tanah Terhadap Transformasi di dalam Tanah

Table 2 Typical rates *(kg ha^{-1} year^{-1})* of soil processes supplying nutrients to crops in temperate agricultural systems and associated typical rates *(kg ha^{-1} year^{-1})* of fertiliser application.

Microbially mediated process	Land use	Soil supply	Reference	Fertiliser[1]
N_2 fixation (white clover)	Grassland	13-280	Ladha *et al.* 1992	290
N mineralisation	Grassland	65-400	Jarvis *et al.* 1996	290
S mineralisation	Grassland	18-36	Sakadevan *et al.* 1993	20-32
P mineralisation	Grassland	23	Brookes *et al.* 1984	28
N mineralisation	Arable	50-130	Jarvis *et al.* 1996	200
S mineralisation	Arable	2-6	Kirchmann *et al.* 1996	10-16
P mineralisation	Arable	5	Brookes *et al.* 1984	20

[1] Fertiliser recommendation rates derived from Anon. (2000) where: Grassland = Cut and grazed sward of moderate fertility on medium soil, maintenance application of P; Arable = Dominantly cereal based rotation in moderate rainfall areas on medium soils, maintenance application of P.

Pengaruh Mikroba Tanah Terhadap Struktur Tanah

- Fungi, dengan Hyfa yang dihasilkannya dapat mengikat partikel tanah membentuk agregat
- Bakteri dan mikroba lainnya menghasilkan metabolit sekunder berupa gum yang berperan sebagai perekat dalam pembentukan agregat.

Macroaggregat Model and Hierarchy

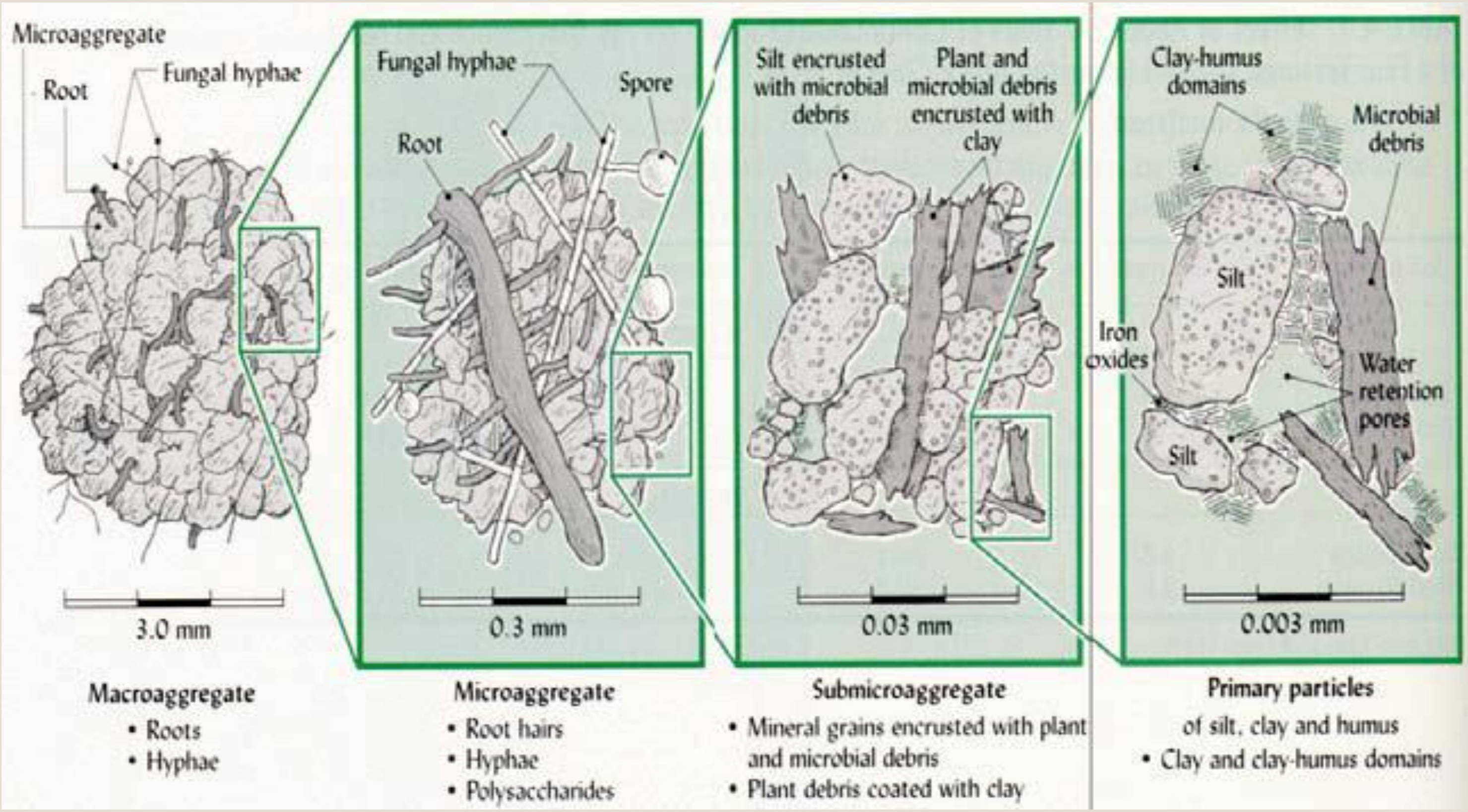


Figure 2. From Tisdall & Oades, 1982

Figure 3. Roots, fungi hyphae. and polysaccharides stabilize soil macro-aggregates and promote good soil structure. From Dr. João de Moraes Sá.

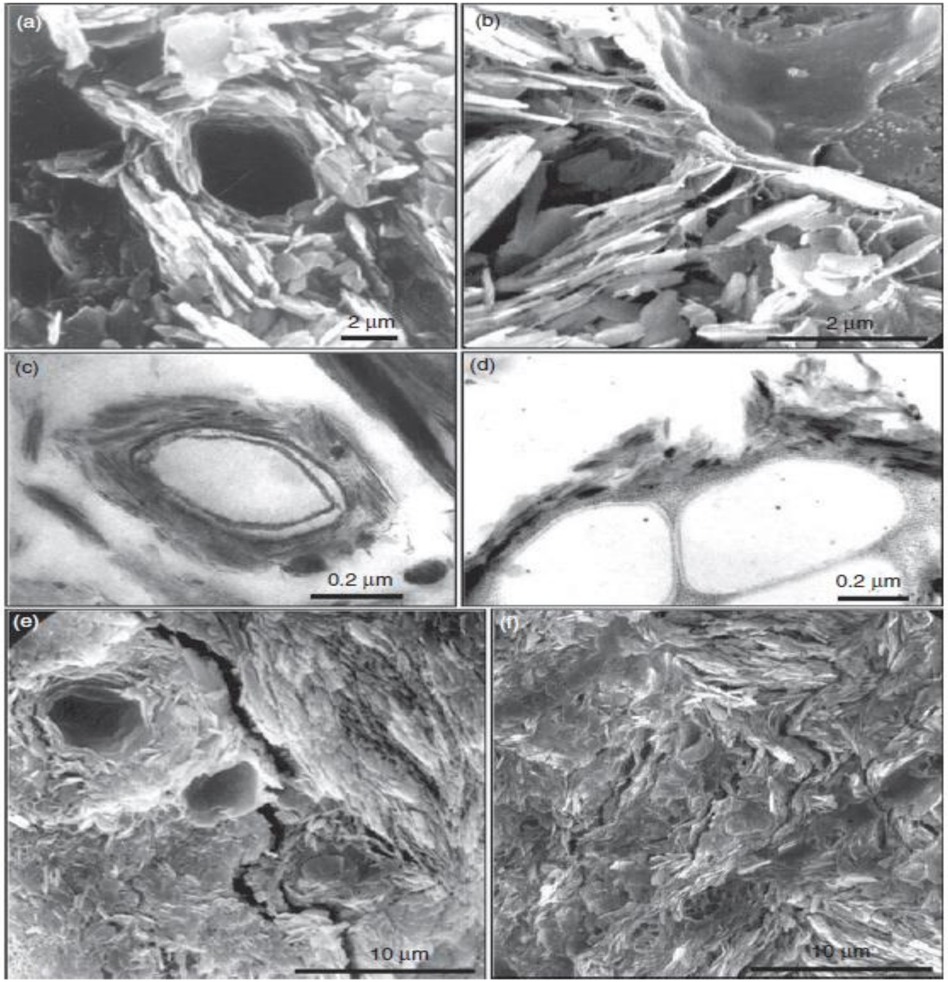



Fig. 3.1. Changes in soil structural form due to microorganisms. (a) *Chaetomium* sp. growing in kaolinite, by cryoSEM (Dorioz *et al*., 1993); (b) detail of contact between *Fusarium oxysporum* cell and kaolinite, by cryoSEM (Dorioz *et al*., 1993); (c) remnants of bacteria in a luvisol with oriented clay particles, by TEM (Chenu, unpublished); (d) remnants of bacterial colony in a luvisol with oriented clay particles, by TEM; extracellular polysaccharides are stained with silver and appear as black dots (Chenu, unpublished); (e) cracks in *Trichoderma viride* cultures in kaolinite after alternate 10/0.01 MPa, by cryoSEM (Dorioz *et al*., 1993); (f) cracks in *Rhizoctonia solani* cultures in kaolinite after alternate pF2/pF5.8, by cryoSEM (from Dorioz, unpublished).

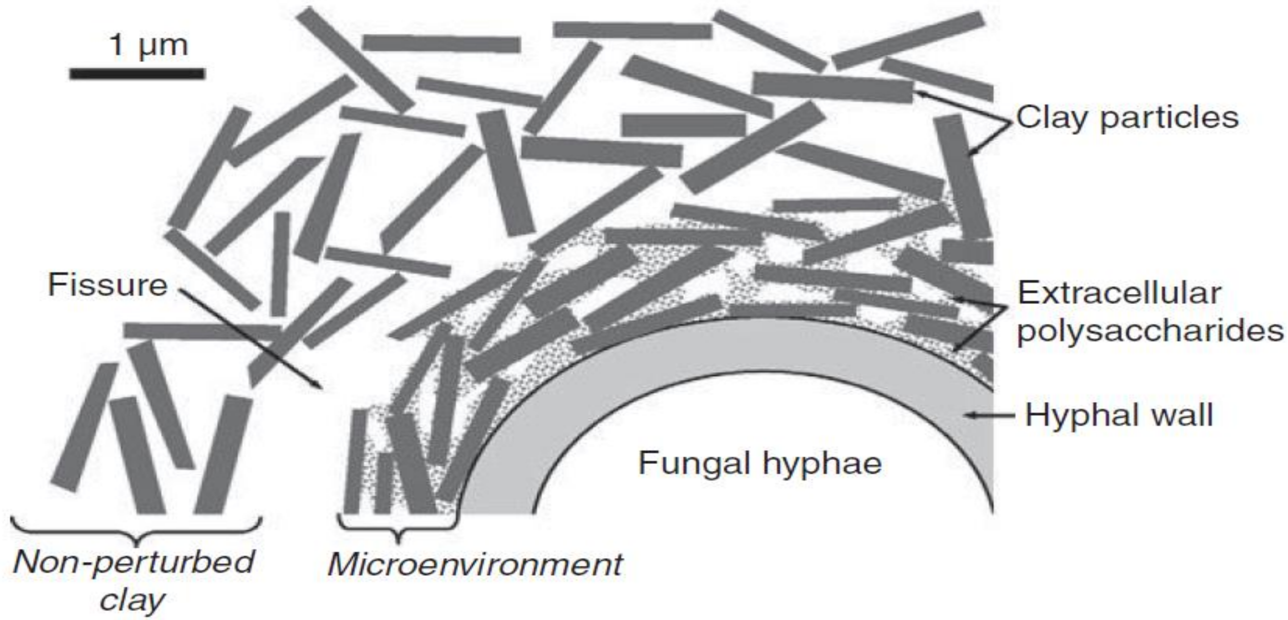


Fig. 3.2. Schematic representation of structural changes in the vicinity of a growing fungal hypha (adapted from Robert and Chenu, 1992).

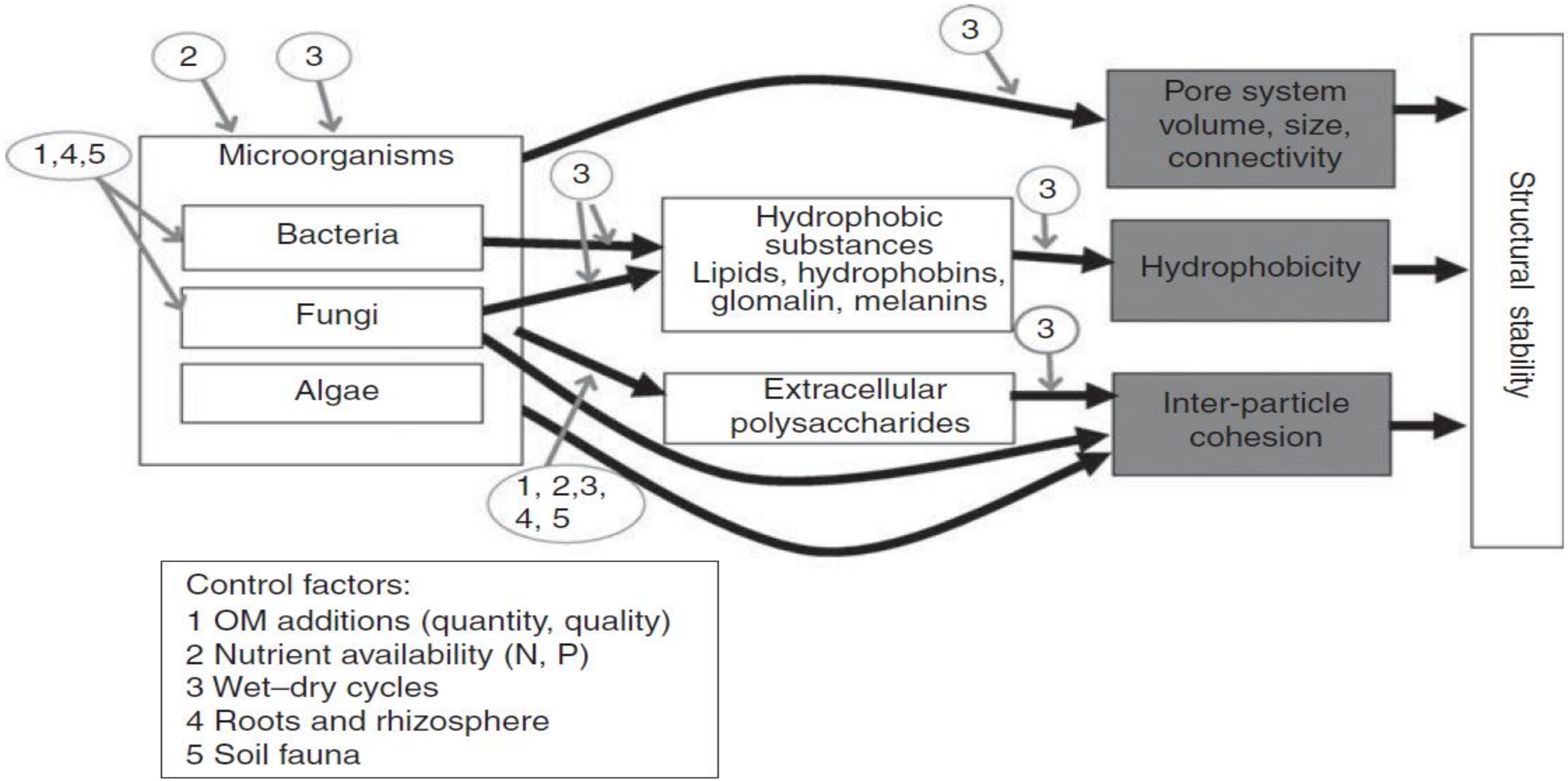


Fig. 3.4. Schematic representation of the main mechanisms by which microorganisms stabilize soil aggregates.

Table 3.1. Correlations between aggregate stability and microbial characteristics (determination coefficients).

Reference	Soil type or texture	Total organic C	Total polysaccharides	Dilute acid-soluble polysaccharides	Hot water-soluble polysaccharides	Microbial biomass	Hyphal length	Other fractions measured
Angers and Mehuis (1989)	Clay			0.63				
Angers *et al*. (1993)	Clay	0.001 (ns)		0.28	0.43	0.33		
Angers (1992)	Loam	0.6				0.4 (ns)		
Angers *et al*. (1999)	Sandy loam, Podzol	0.77		0.8		0.57		
Ball *et al*. (1996)	Loam	0.83	0.97	ns	0.98			
Bethlenfalvay *et al*. (1999)	Silt loam						0.565	
Bissonnette *et al*. (2001)	Silty clay	0.95		0.89		0.9		
Capriel *et al*. (1990)	20% clay/63% silt					0.82		Lipids
Carter (1992)	Sandy loam, Podzol	0.942				0.947		
Carter *et al*. (1994)	Sandy loam	ns		< 0.25	< 0.25	ns		
Chan and Heenan (1999)	Oxic Paleustalf	ns				0.64		
Chantigny *et al*. (1997)	Silt clay loam and Clay loam			0.42/0.05		ns		Fungal glucosamine ($r = 0.68$); bacterial muramic acid ($r = 0.48$)
Degens *et al*. (1994)	Sandy loam	ns		ns	0.05	ns	ns	
Degens and Sparling (1996)	Sandy, Podzol			ns	ns	0.54–0.83		
Degens *et al*. (1996)	Sandy						0.41	
Drury *et al*. (1991)						0.26		
Denef and Six (2005)	Loam, illitic					0.59		
	Clayey, ferralsol					0.21		
Haynes and Swift (1990)	Silt loam	0.58	0.57 (ns)		0.74			
	Sandy loam	0.66	0.67	0.56 (ns)	0.83			
Haynes *et al*. (1991)	Silt loam	0.77	0.75	0.76	0.84	0.957[a]		
	Clay loam	0.72	0.76	0.6 (ns)	0.79			
Haynes (1999)	Silt loam	0.92			0.72 (ns)	0.8		Mineralizable C
Haynes (2000)	Silt loam	0.61	0.66		0.99			

Jastrow *et al.* (1998)	Silt loam	0.43			0.55	0.65	0.89	
Kiem and Kandeler (1997)	6–30% clay	0.34				0.59–0.87		
Kinsbursky *et al.* (1989)	3–44% clay				0.58–0.85			
Lax and García-Orenes (1993)	Clay loam		0.88					
Metzger *et al.* (1987)	Sandy clay loam		0.5		0.68		0.74	
Perfect *et al.* (1990)						0.11		
Roberson *et al.* (1991)	Loam	ns				0.71		Heavy-fraction carbohydrates ($r = 0.9$); light-fraction carbohydrates (r = ns)
Roberson *et al.* (1995)	Sandy loam	ns				ns in summer: 0.52		Heavy-fraction carbohydrates with slacking resistance ($r = 0.74/0.81$)
Roldan *et al.* (1994)	Loamy clay			0.66–0.28				
Sparling (1992)						0.88		
Tisdall and Oades (1980)	Red–brown earth	0.93					0.77	
Wright and Upadhyaya (1998)	37 soils of varying texture	0.65						0.84 (easily extractable glomalin)

ns, not significant.
[a]Calculated.

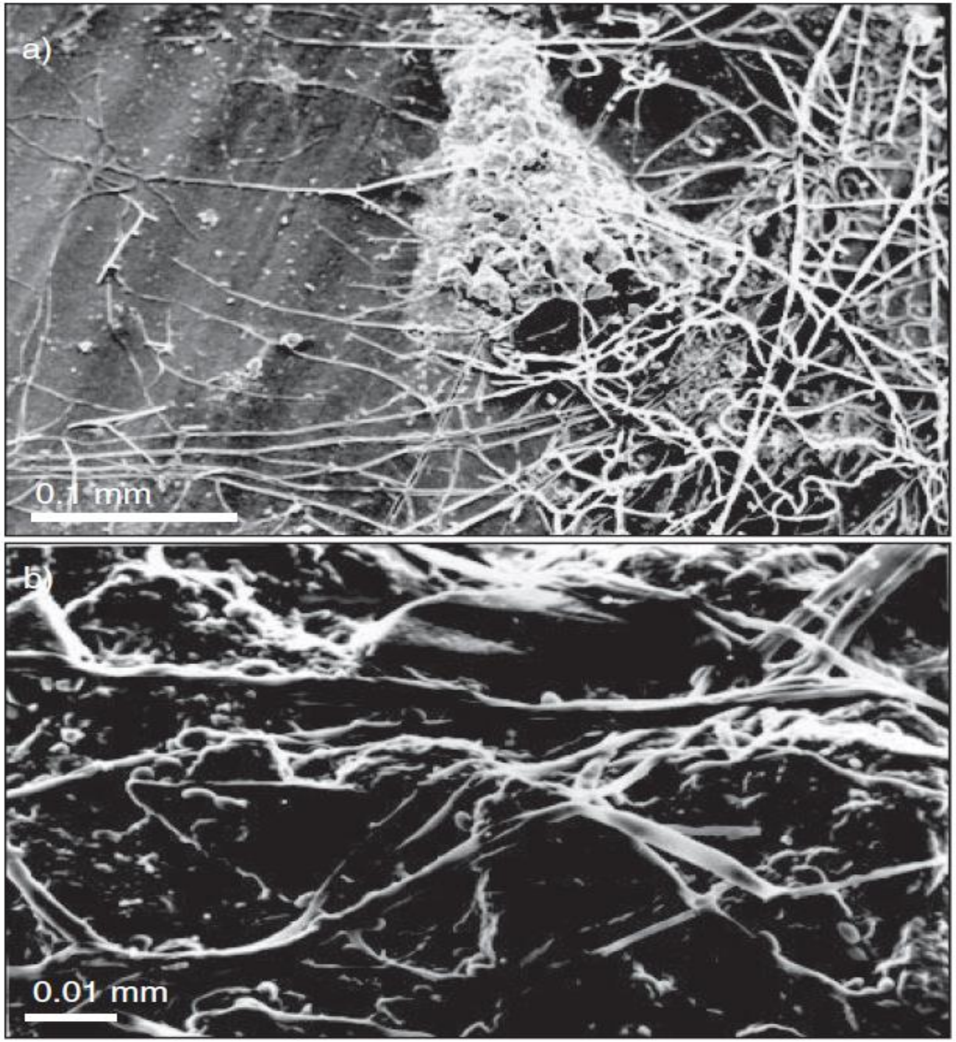


Fig. 3.6a, b. Physical entanglement of soil particles by fungal hyphae. Entanglement is related to the growth of saprophytic fungi decomposing wheat straw (from Chenu and Angers, unpublished).

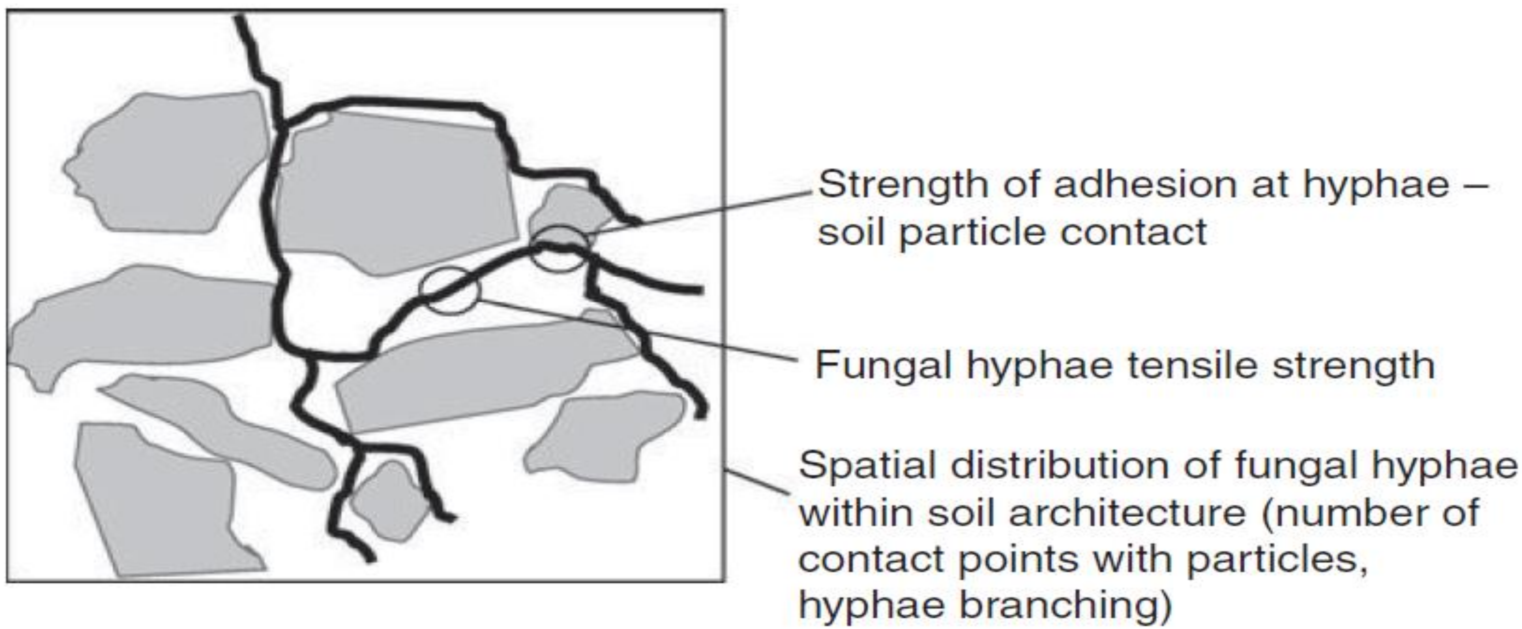


Fig. 3.7. Properties involved in the efficiency of physical entanglement by fungal hyphae.

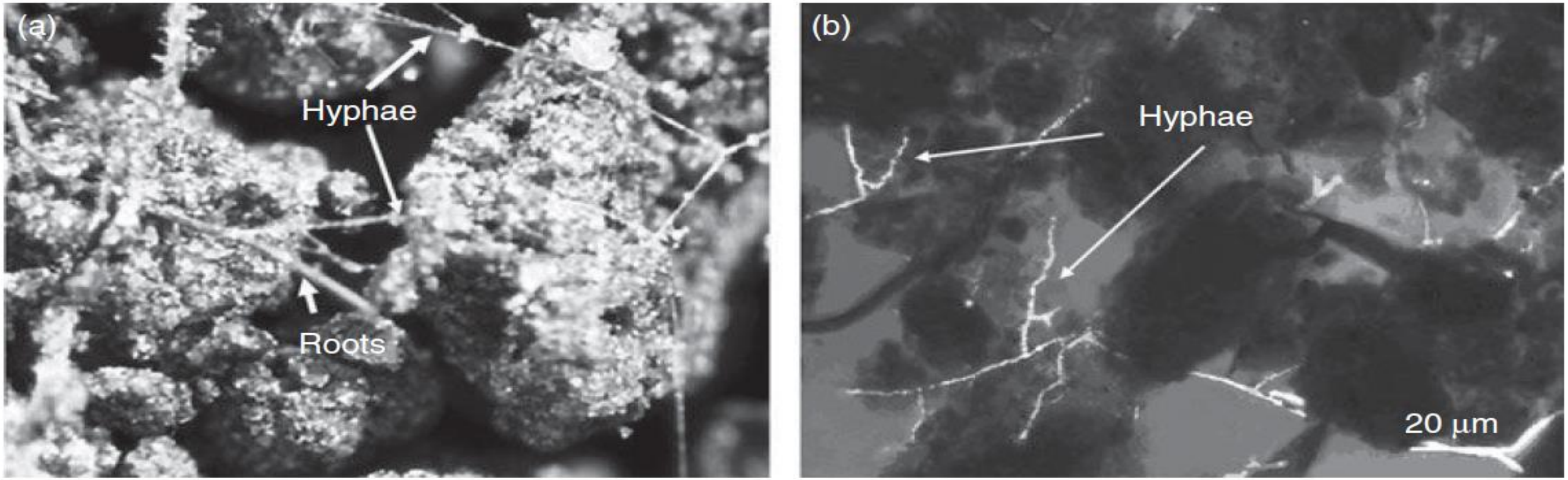


Fig. 8.1. The remarkable – and hugely consequential – ability of fungi to bridge the gaps between soil aggregates. (a) The arbuscular mycorrhizal fungus *Glomus etunicatum* growing in a highly aggregated silt loam (photograph by R.M. Miller); (b) the plant pathogen *Rhizoctonia solani* has a similar growth habit well adapted to growing through the soil pore network (from Harris *et al.*, 2003).

Table 3.2. Hydrophobic/hydrophilic fungi. Hydrophobicity may depend not only on species but also on culture conditions.

Hydrophobic forms		Hydrophilic forms	
Basidiomycetes			
Laccaria bicolor *Paxillus invollutus*	Smits *et al.* (2003)	*Thelephora terrestris, Cenococcum geophilum, Laccaria laccata*	Unestam (1995)
Hebeloma crustiliforme	Smits *et al.* (2003)	Hevbeloma crustuliniforme	Unestam (1995)
Tricholoma sp. *Cortinarius umbonatus* *Chlatrus gracilis* *Clavaria aurantia*	Bond and Harris (1964)		
Suillus bovinus	Smits *et al.* (2003)		
Marasmius oreades	York and Canaway (2000)		
Coriolus versicolor *Phanerochaete chrysosporium*	White *et al.* (2000)		
Ascomycetes			
Cladosporium sp.	Smits *et al.* (2003)		
Deuteromycetes			
		Fusarium oxysporum *Trichoderma harzianum*	Smits *et al.* (2003)

Table 3.3. Estimated residence/lifetime of selected aggregating agents.

Aggregating agent	Residence/ lifetime (days)	Conditions	Reference(s)
Live hyphae	3–5		Staddon *et al.* (2003)
Dead hyphae	160	1-point data, calculation assuming first-order kinetics	Steinberg and Rillig (2003)
Extracellular polysaccharides	20	Bacterial polysaccharide luvisol, 24°C	Cohen (2002)
	5–10	Bacterial polysaccharide	Andreyuk *et al.* (1986)
Glomalin	240	1-point data, calculation assuming first-order kinetics	Steinberg and Rillig (2003)

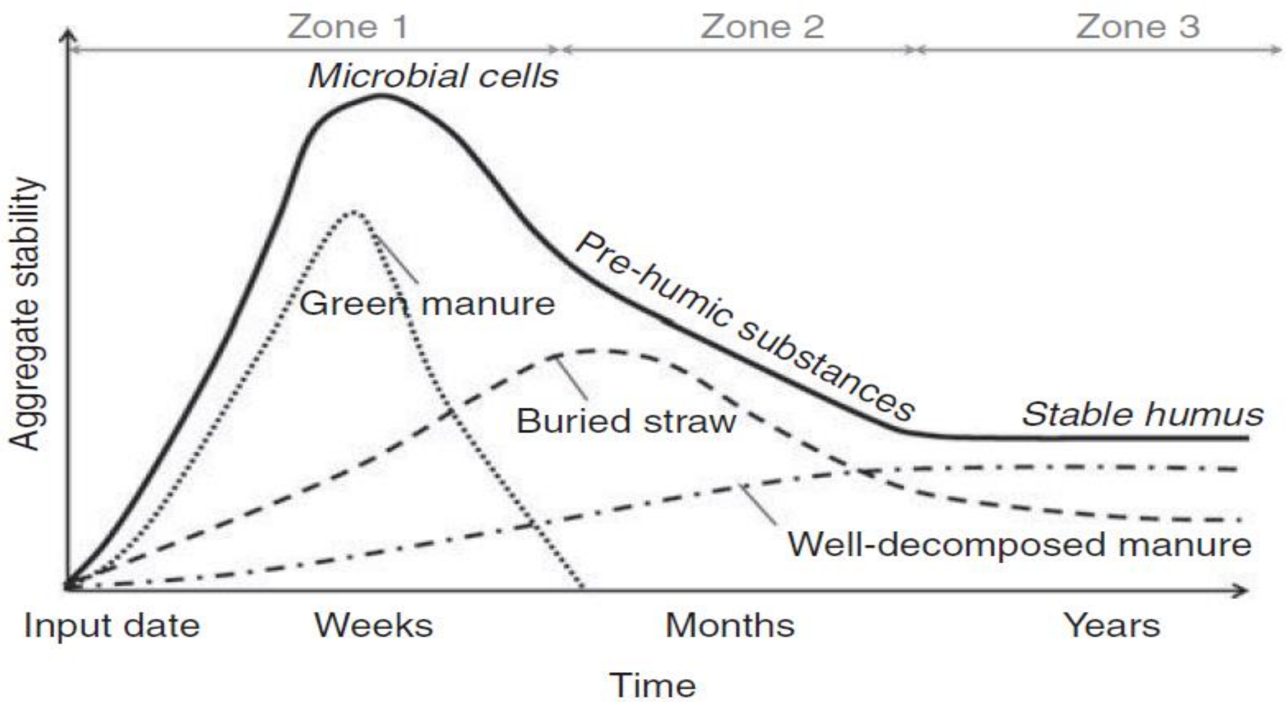


Fig. 3.9. Monnier's (1965) conceptual model: evolution of soil structural stability after the addition of organic matter characterized by either high decomposability (green manure), intermediate (buried straw) or low (well-decomposed manure).

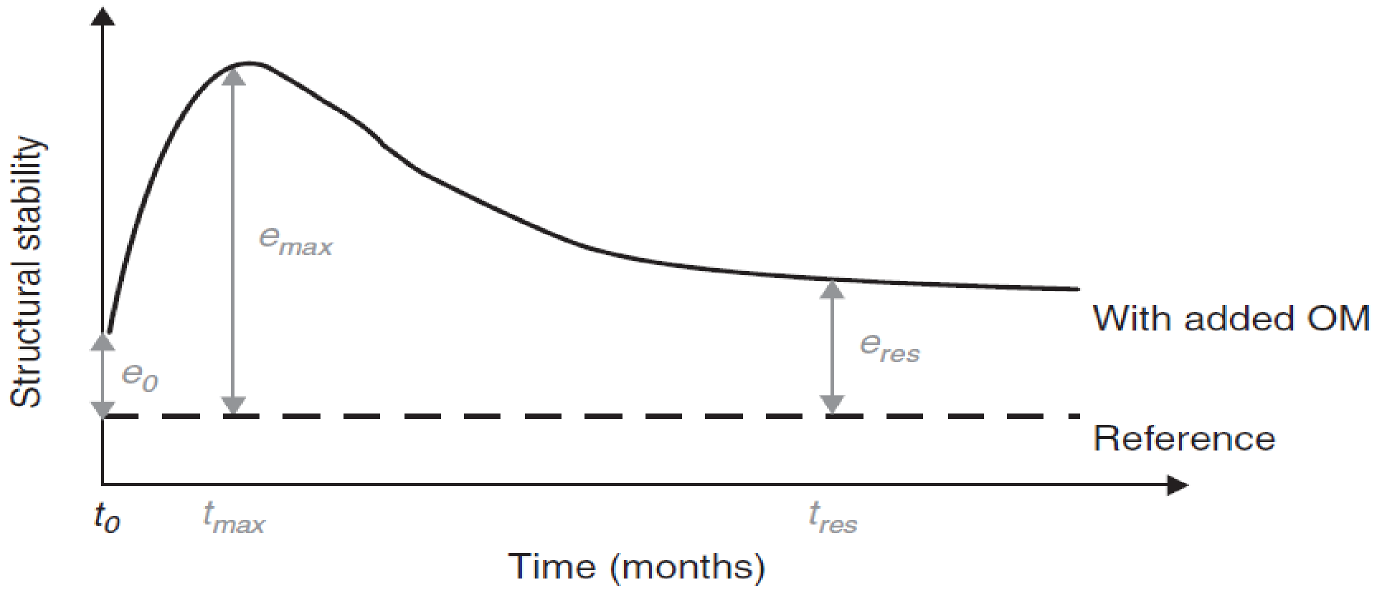


Fig. 3.10. Possible impacts of addition of organic matter to soil on structural stability and parameters that would allow the prediction of temporal patterns. t_0, time zero (addition of organic matter); e_0, direct effect of added organic matter at time 0; t_{max}, time at which effect on soil structure is maximal; e_{max}, maximal effect on soil structure; t_{res}, time at which a residual effect is observed (slope of aggregate stability versus time is low); e_{res}, residual effect.

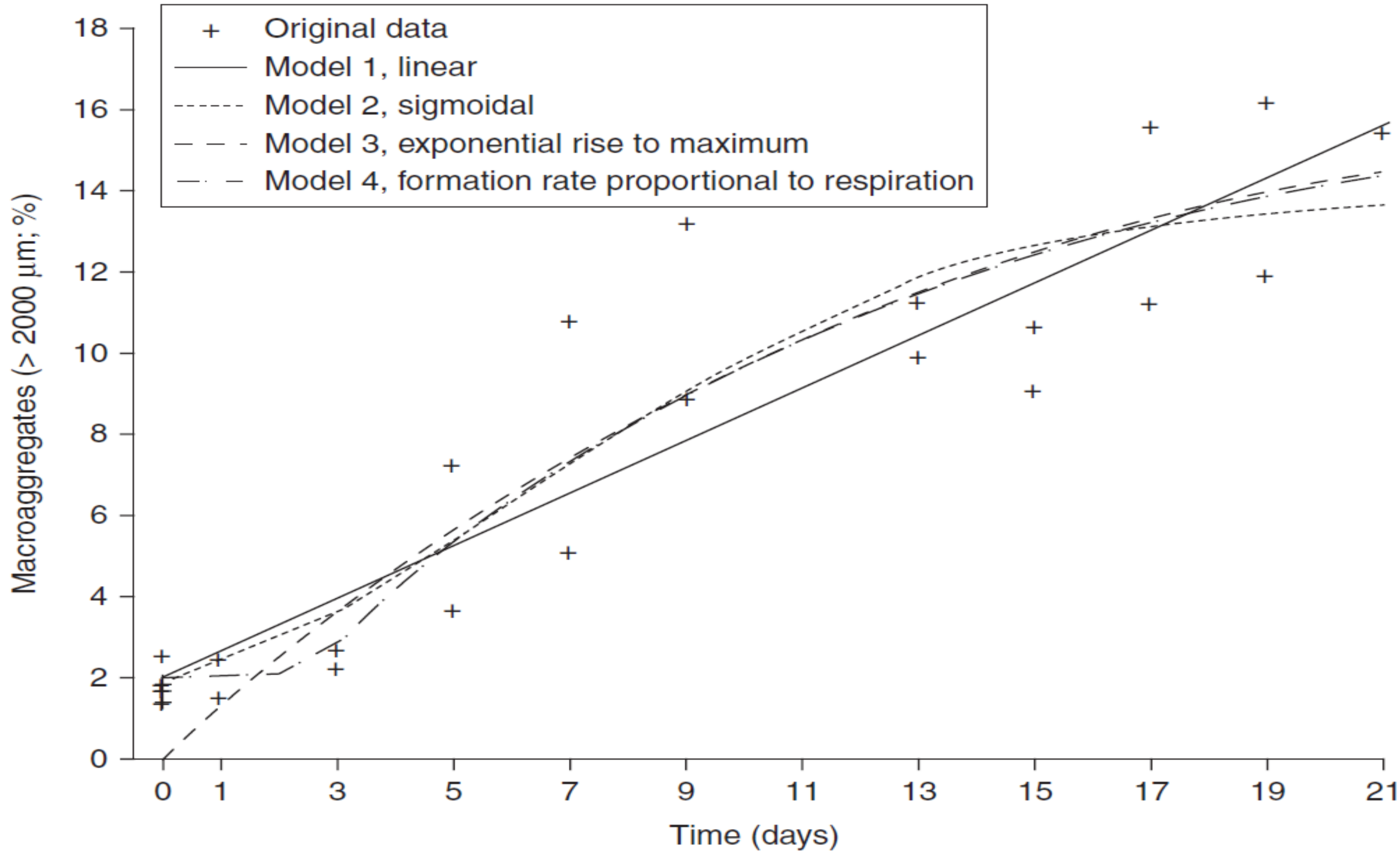


Fig. 3.12. Abundance of water-stable macro-aggregates in a silty loam soil during a 3-week incubation after addition of 1.5 g wheat residue/100 g of soil. The data were fitted using four different models (from De Gryze *et al.*, 2005a).

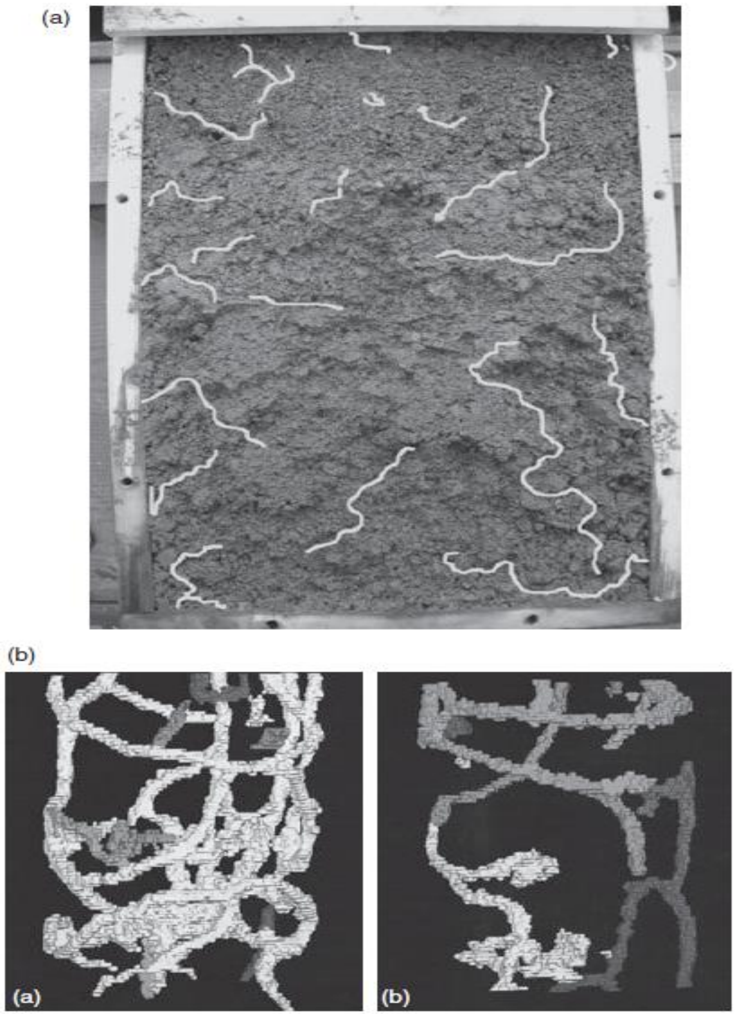


Fig. 4.1. The burrowing behaviour of the anecic earthworm *Lumbricus terrestris* has a strong influence on the architecture of the soil, creating semi-permanent burrows within the soil matrix. (a) Soil cross-section profile of an experimental Evans box showing the extent of earthworm-burrowing activity for foraging by *L. terrestris* in a sandy loam soil after 30 days. Width of box = 300 mm (photo courtesy of M. Bartlett); (b) 3D images generated using X-ray computed tomography of void spaces associated with *L. terrestris* activity within a soil monolith (from Langmaack *et al.*, 1999).

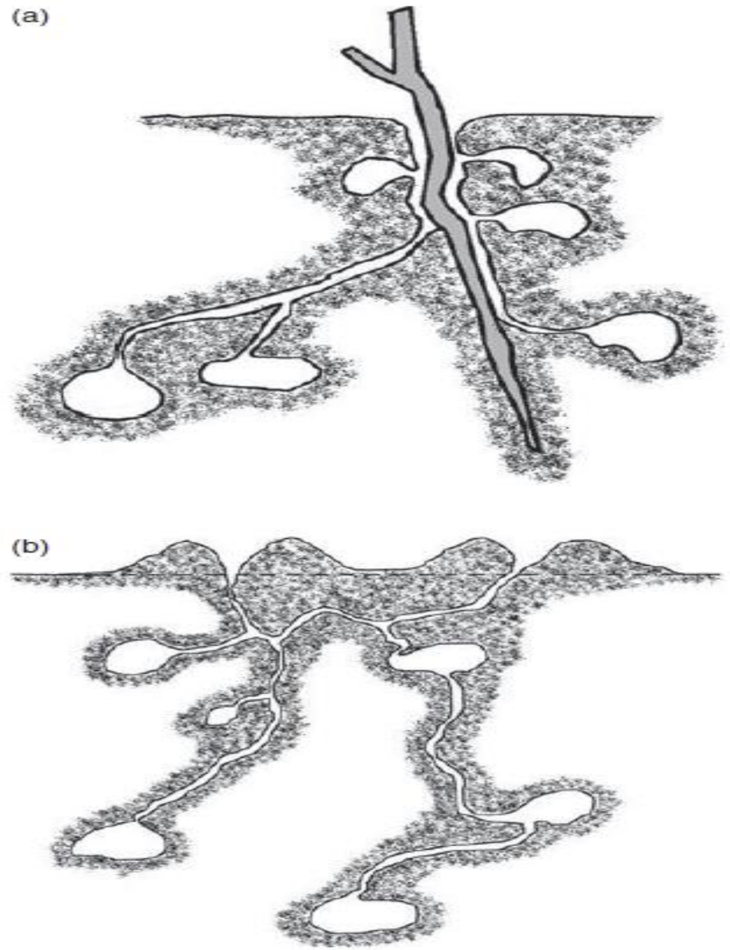


Fig. 4.2. The extent to which ants restructure the soil matrix to form their colony can have significant effects on the total void space of the soil. (a) Colonies may be formed around existing root macropores; (b) soil may be excavated to the surface and modify topographic surface features (from M. Bartlett).

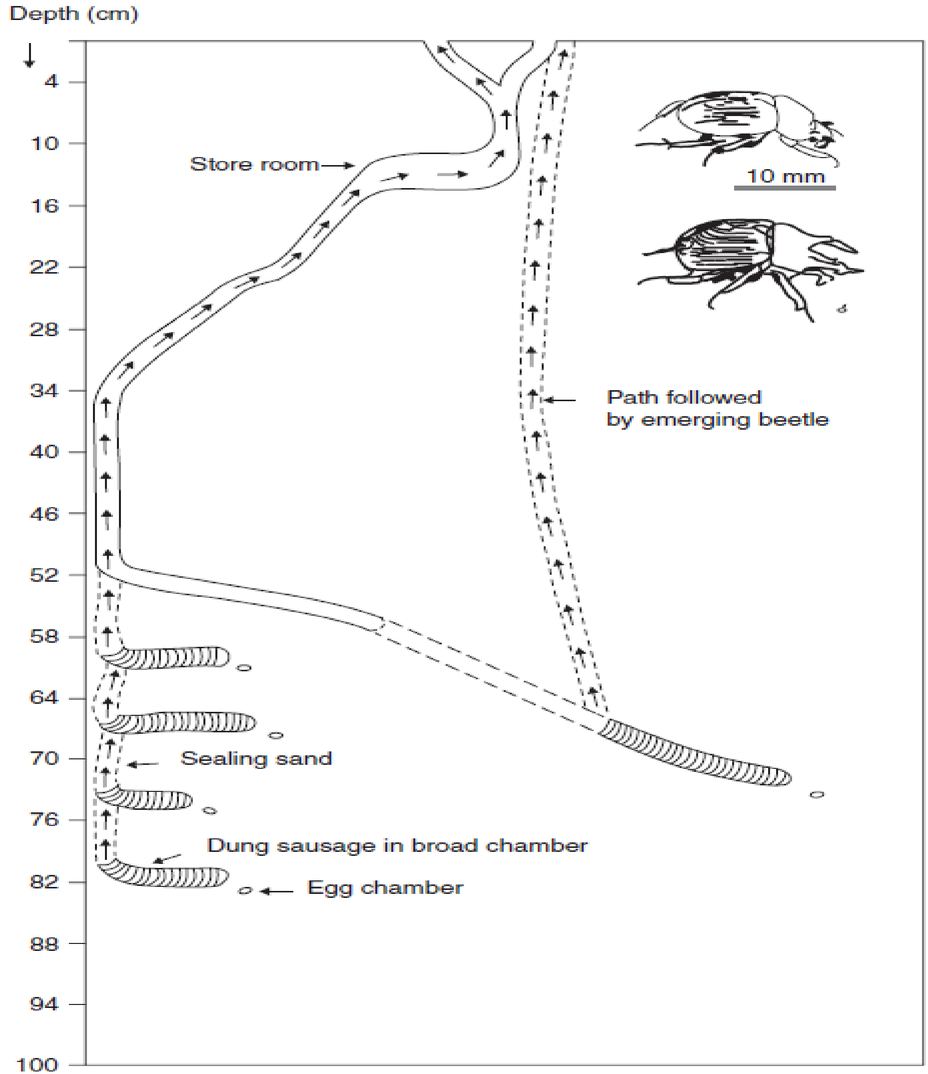


Fig. 4.3. Schematic diagram of the activity and nest structure of a tunnelling beetle *Typhaeus typhoeus* (Minotaur beetle) in a sandy soil (from Brussaard and Runia, 1984).

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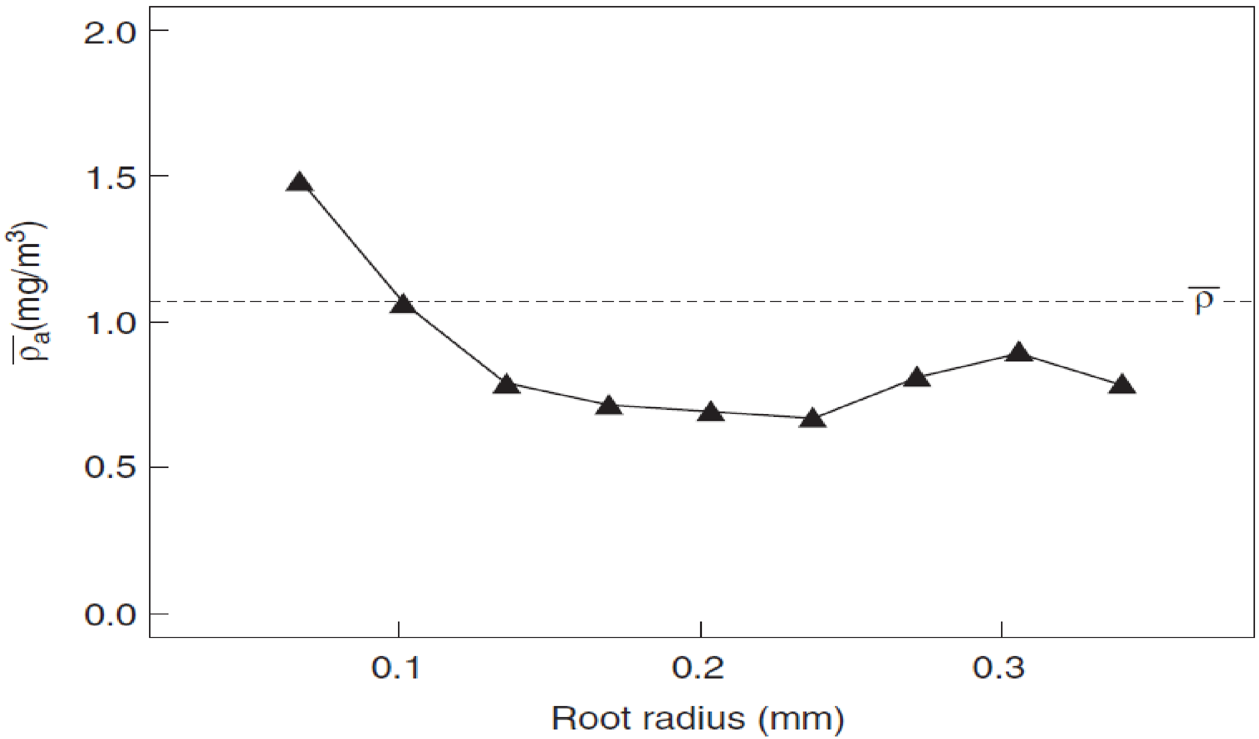

Fig. 5.2. Average soil density (ρ_a) in the immediate vicinity of wheat roots as a function of their radius, which indicates where the roots are growing in the soil density space. Confidence limits are too small to be represented. The broken line represents soil bulk density (adapted from Moran *et al.*, 2000).

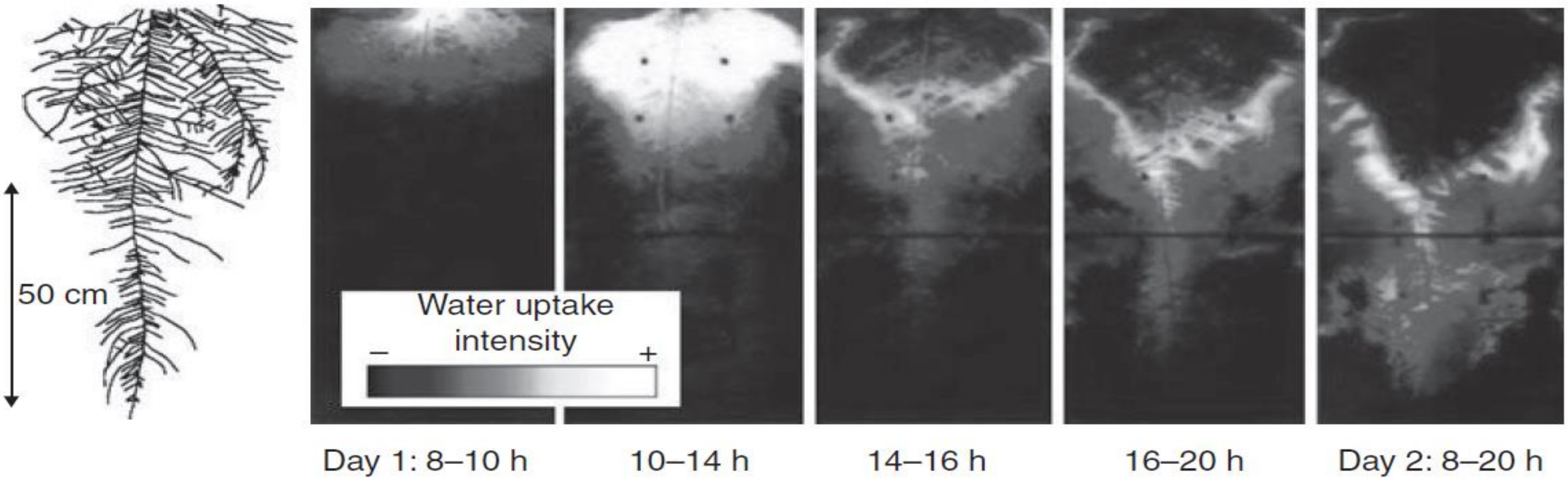

Fig. 5.4. Light transmission difference images of a water extraction front expanding as a 'moving sink' through a sandy growth medium (elapse time expressed as days after cessation of irrigation). Tap-rooted system of a c. 50-day-old narrow-leaf lupin (*Lupinus angustifolius*) (adapted from Garrigues *et al.*, 2006).