High efficient utilization of water and fertilizer in Greenhouse Vegetable production

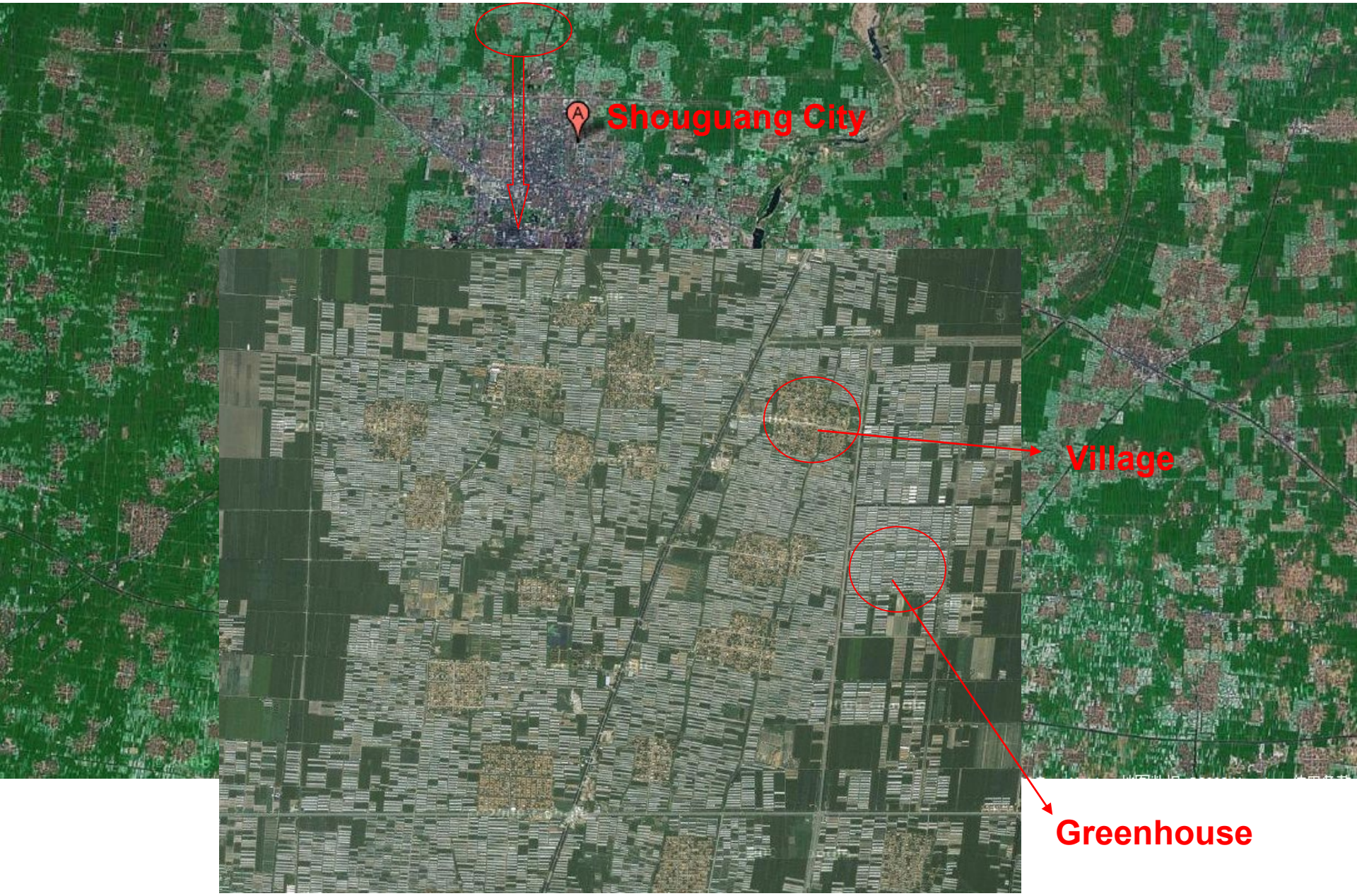
Chen Qing

College of Resources and Environmental Sciences
China Agricultural University

Email：qchen@cau.edu.cn

Content

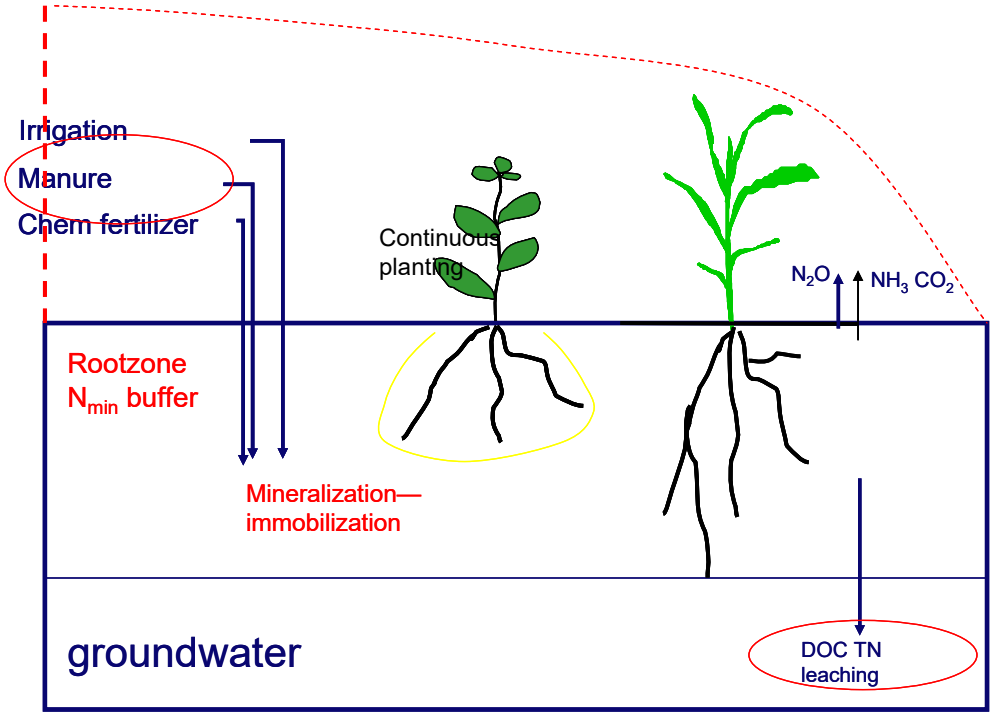
1. **Bottle neck in high use efficiency of water and fertilizer in greenhouse vegetable production**
2. **Fertigation: basic demand to improve high UE of water and fertilizer**
3. **High efficient Utilization of water and fertilizer: Soil health and crop health**
4. **Summary**


Shouguang City
Village
Greenhouse

China is also the largest country of protected-field vegetable production

The planting area of protected-field vegetable was 5.01 million ha, 22.6% of total area in China in 2016

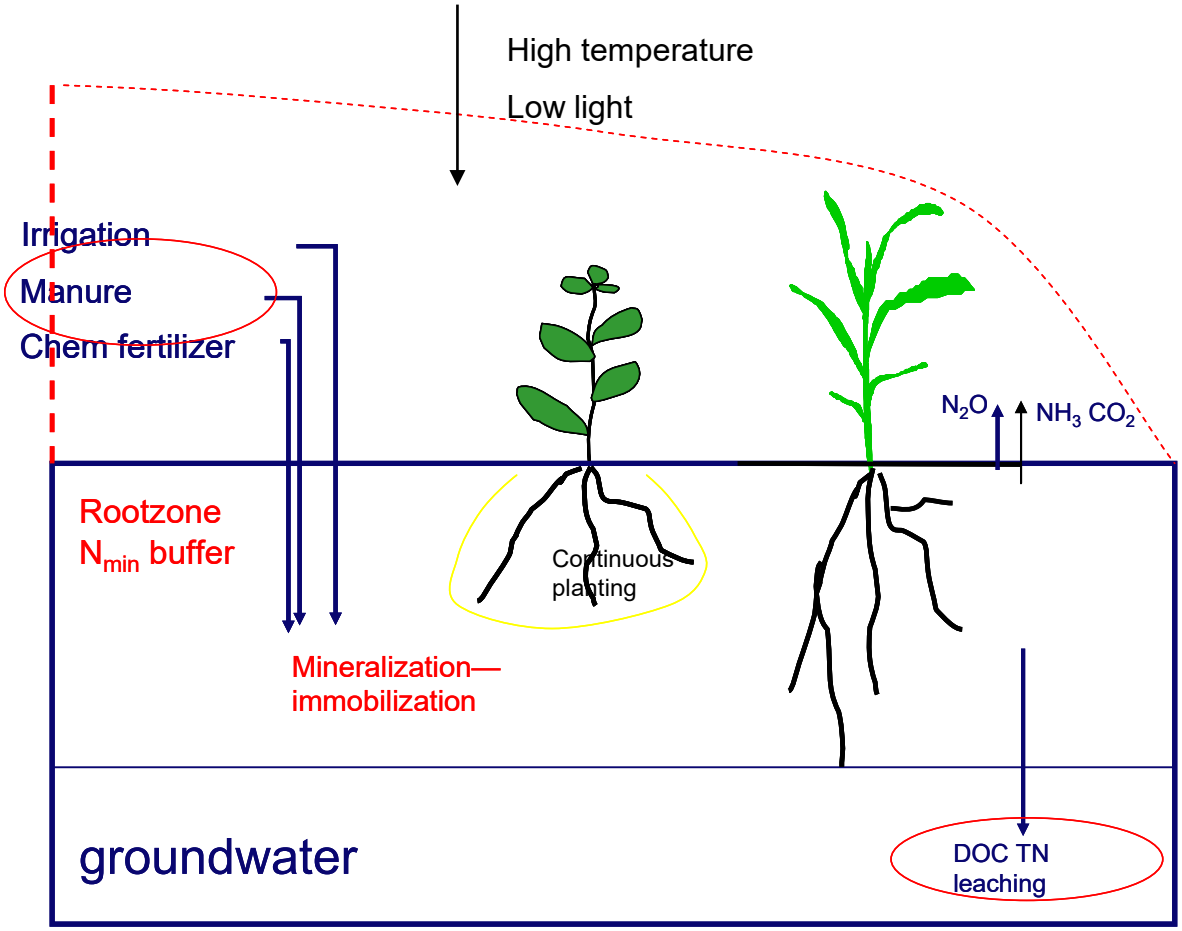
Low temperature and soil barriers from continuous planting caused very poor root system and low P uptake rate, consequently high phosphate is needed in rootzone soil solution.



Special micro-environmental condition in greenhouse

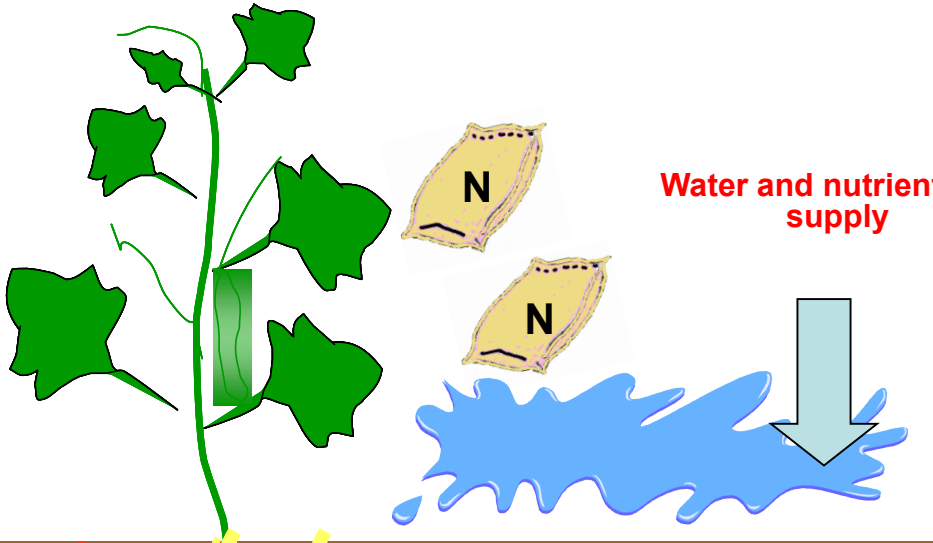
Soil quality change:

- Nutrient leaching and soil acidification
- High nutrient accumulation and secondary salinity
- Low ratio of C/N, low soil biodiversity and more fungi disease
- Nematode etc



Conventional water and nutrient input

Maximum yield is the goal of farmer's nutrient management, however, this will increase nutrient loss



Shallow root system needs frequent irrigation/fertilization with low rate

To uncover the secret: why farmers use high rate of fertilizer?

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Agriculture Ecosystems & Environment

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Environmental implications of low nitrogen use efficiency in excessively fertilized hot pepper (*Capsicum frutescens* L.) cropping systems

J.H. Zhu [a,b], X.L. Li [a,*], P. Christie [a,c], J.L. Li [a]

[a] *Key Laboratory of Plant Nutrition, Ministry of Agriculture, Key Laboratory of Plant–Soil Interactions, Ministry of Education and Department of Plant Nutrition, China Agricultural University, Beijing 100094, China*

[b] *Institute of Forest Ecology, Environment and Protection, Chinese Academy of Forestry, Beijing 100091, China*

[c] *Agricultural and Environmental Science Department, Queen's University Belfast, Newforge Lane, Belfast BT9 5PX, UK*

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Available online 24 June 2005

Nitrogen rates (kg ha^{-1}) distribution balance for a cropping season.

Green-house	N inputs						Total	N outputs				Soil mineral N[a] variation	Unaccounted N
	Mineral fertilizer		Organic fertilizer		Irrigation water			Nitrate leaching		Crop uptake			
	Rate	%	Rate	%	Rate	%		Rate	%	Rate	%		
1	325	68	8	2	144	30	579	169	29	219	38	−39	231
2	190	30	170	27	268	43	493	154	31	227	46	−3	115
3	493	38	310	24	482	38	1316	261	20	298	23	−48	806
4	207	31	154	23	300	45	694	152	22	122	18	−225	645
5	501	58	190	22	169	20	973	199	20	289	30	−50	535
6	504	39	185	14	603	47	1296	347	27	196	15	63	690
7	300	57	166	32	59	11	552	158	29	296	54	−75	173
8	328	56	186	32	73	12	565	155	27	244	43	−232	401
9	391	34	240	21	523	45	1060	255	24	366	35	−514	953
Average	360	46	179	22	298	32	836	183	22	251	33	−125	528

[a] Variation in soil mineral N content (100 cm depth).

Song, et al., 2009

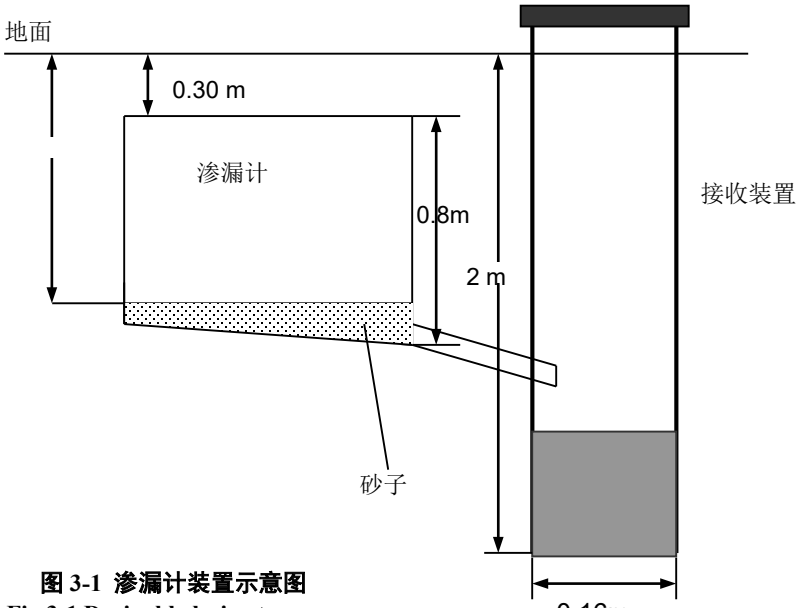
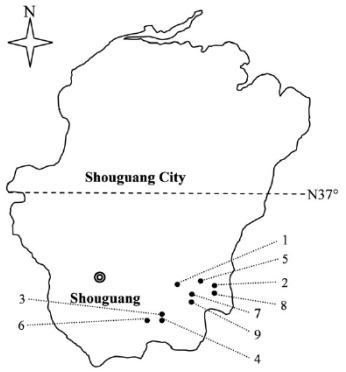


图 3-1 渗漏计装置示意图
Fig.3-1 Drainable lysimeter

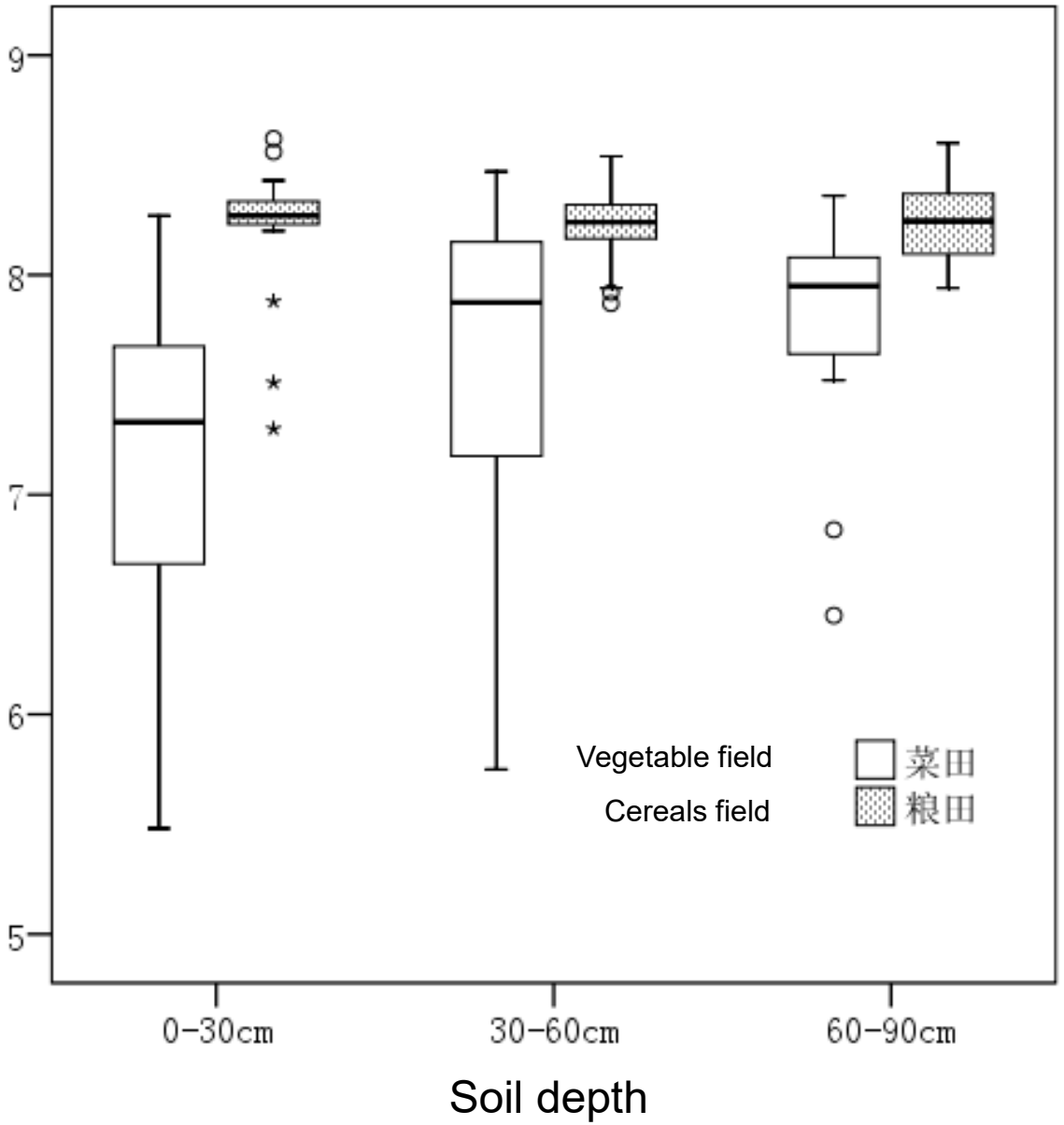


Unsustainable **Bottle necks**:

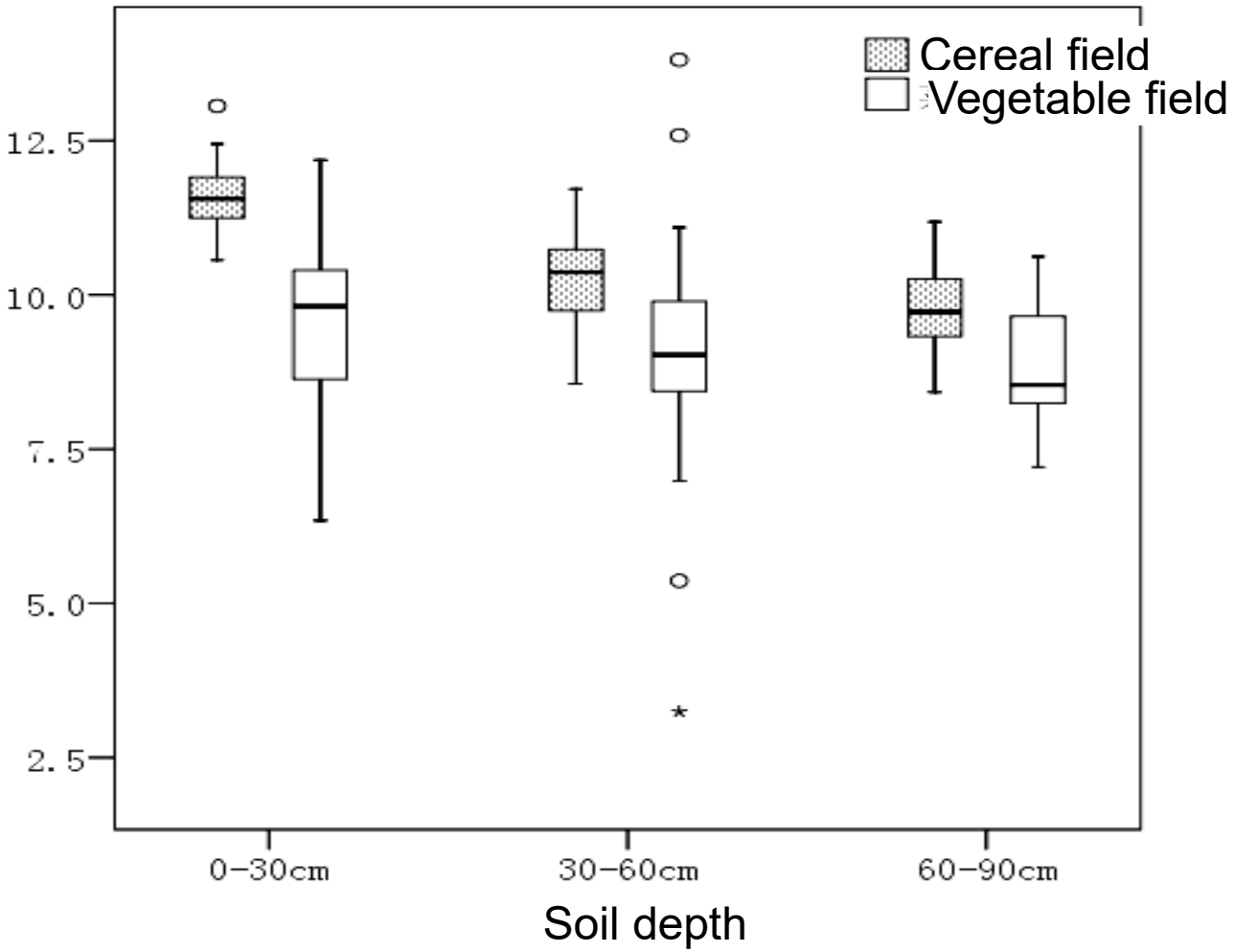
- Soil borne diseases
  - Crop rotation
  - Disease resistance compost types (?)
  - Soil sterilization
- Nematodes
  - Rootstocks
  - Crop rotation
  - Bio-fumigation (?)
  - Soil acidification

Comparison of soil pH change between cereal and vegetable fields in Shouguang,

n=20



Lei, 2008



Comparison of soil ratio of carbon to nitrogen between cereal and vegetable field in Shouguang, n=20

Lei, 2008

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Drip irrigation is the most efficient way of delivering water & fertilizers

- FERTIGATION

Regardless your injection devices

You must have a very good irrigation uniformity

Design, a good product, maintenance

Irrigation Management Measurement Methods

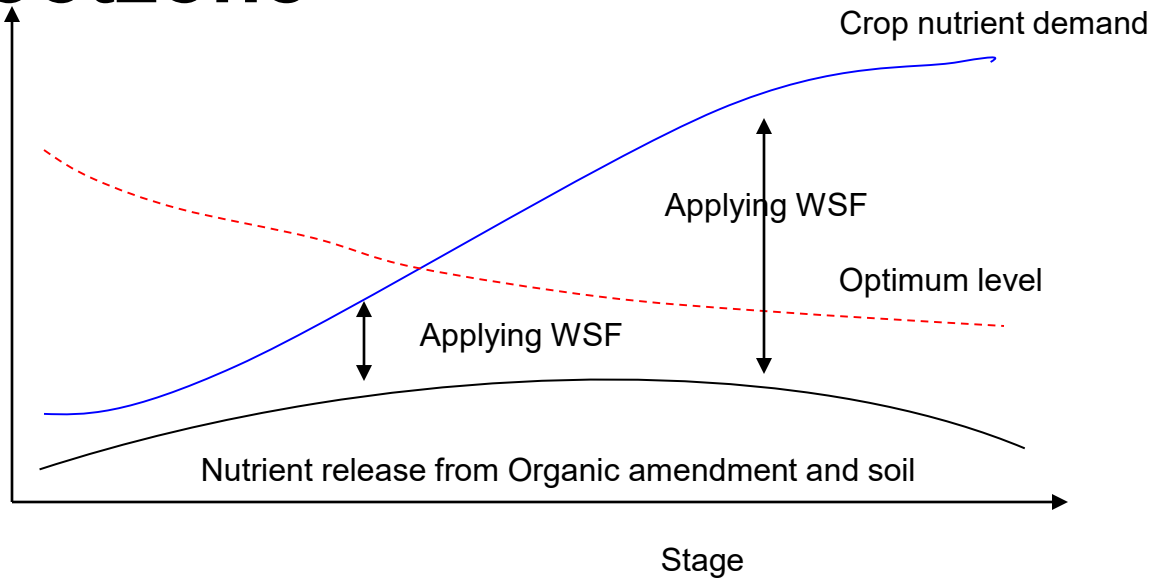
- Human Observations
  - Crop Appearance
  - Hand Feel of Soil
  - When Your Neighbor Irrigates
  - Personal Calendars
- Field Sampling Observations
  - Neutron Probe
  - Gypsum Block (Watermark)
  - Turgor Pressure Sensor (leaf)
  - Dendrometer (trunk diameter)
  - Infrared Thermometers
- Real-time In-situ Monitoring
  - Tensiometers
  - Capacitance Sensors
  - Time-Domain Reflectometry

Human Observation Methods Used at 4 Times the Rate of ALL Other Methods for Irrigation Management by California Growers

Key1: Soil nutrient concentration in rootzone

Rootzone control and water soluble fertilizer use

Different crops need different nutrient concentrations, which depend on the uptake ratio of N-P-K-Ca -Mg



Nutrient uptake pattern in greenhouse tomato（%DW）

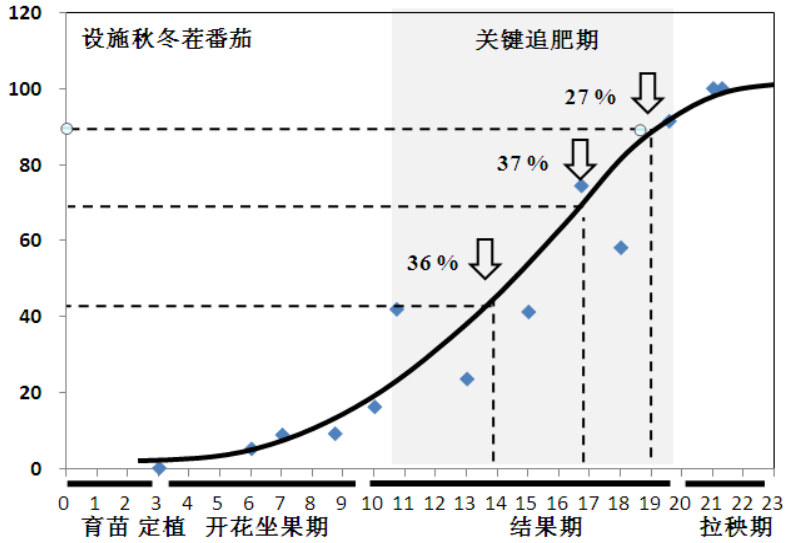
	Laminae	Stem	Side shoots	Vegetative total	Fruits	Total
N	23,3	7,9	7,5	38,7	61,3	100
P	19,9	15,1	4,8	39,8	60,2	100
S	71,6	7,6	4,0	83,2	16,8	100
K	18,5	10,8	5,0	34,3	65,6	100
Ca	75,7	15,1	4,1	94,9	5,2	100
Mg	50,3	15,0	4,9	70,2	29,8	100
Dry matter	20,3	13,6	4,2	38,1	61,8	100

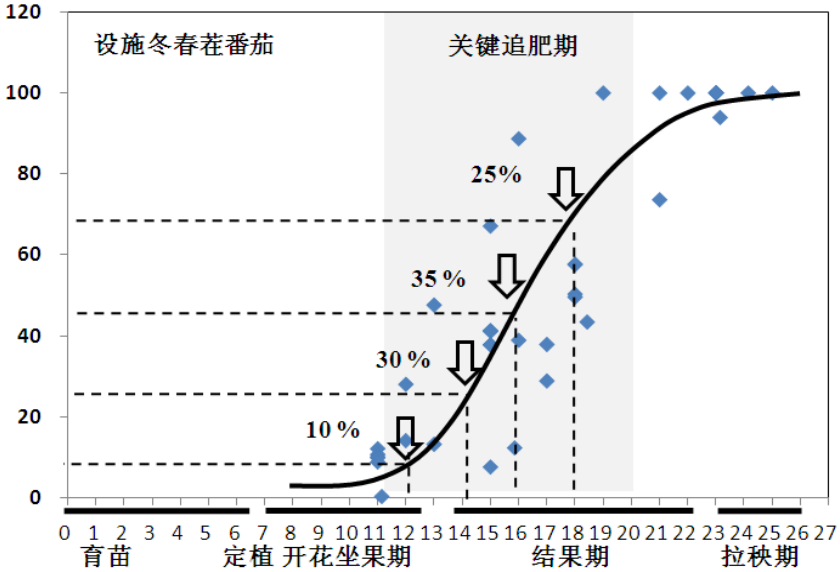
Acta Horticulturae 339, 1993, p 99-112
Nutrient uptake of year round tomato crops-W. Voogt

It should keep optimum nutrient supply in rootzone, otherwise it will cause nutrient lose or yield reduction due to too high or too low level.

氮肥分施：根据生育期决定

N fertilizer splitting :crop growth pattern



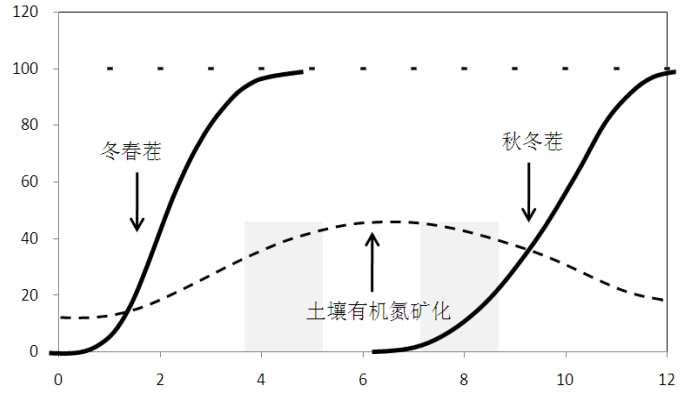


影响因素：光、温 Factors :Light, temperature

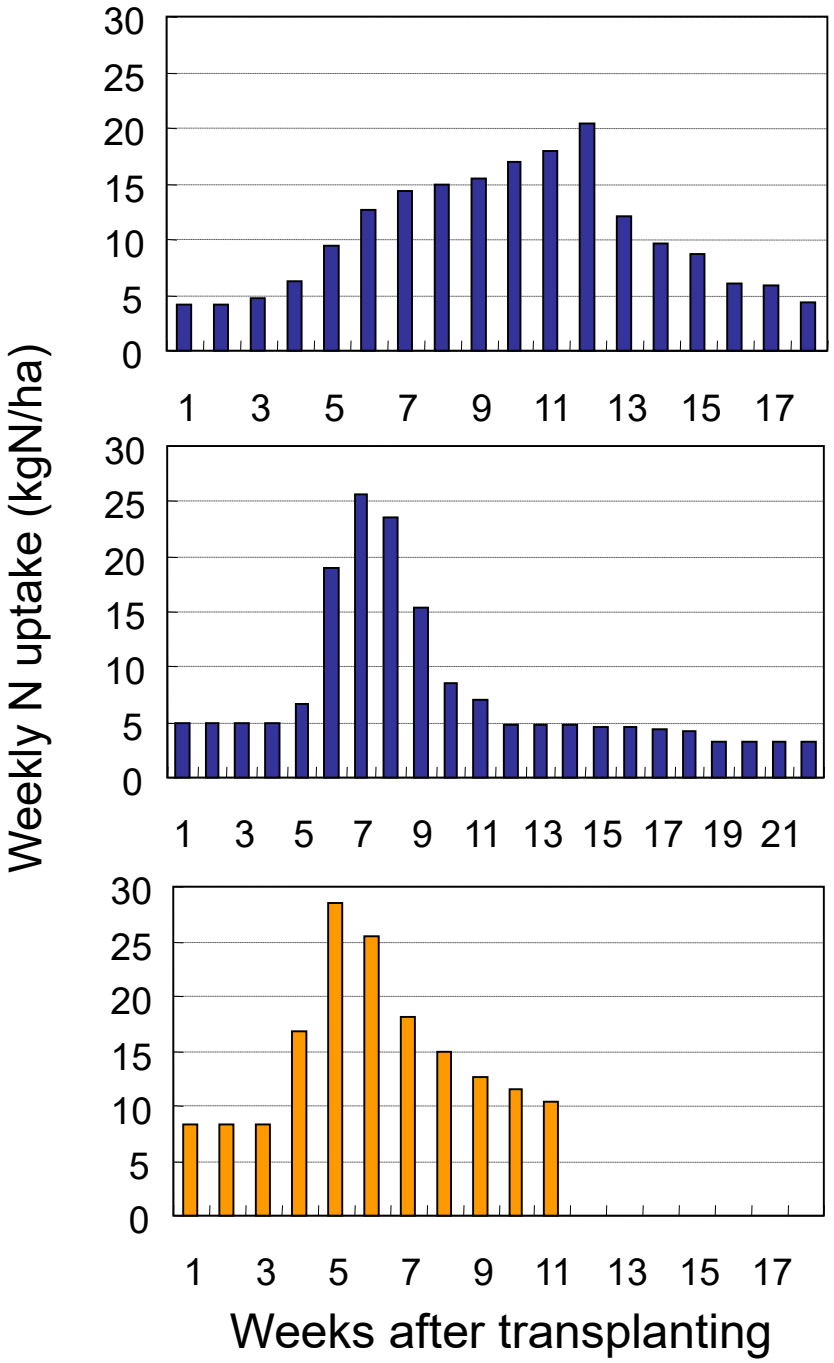
露地番茄 Open field tomato
光照、温度条件好 Light, temperature conditions are good

设施秋冬茬 Facilities for Autumn and Winter
光照条件逐渐变差, 温度逐渐降低
Light down , temperature down

设施冬春茬Facilities for winter and spring
光照条件逐渐转好, 气温逐渐升高Light up , temperature up



Weekly N uptake pattern of tomato in different growth seasons in North China Plain



Winter-spring season in greenhouse

Data from Tang (2004); Liu (2004，2005)，et al

Autumn-winter season in greenhouse

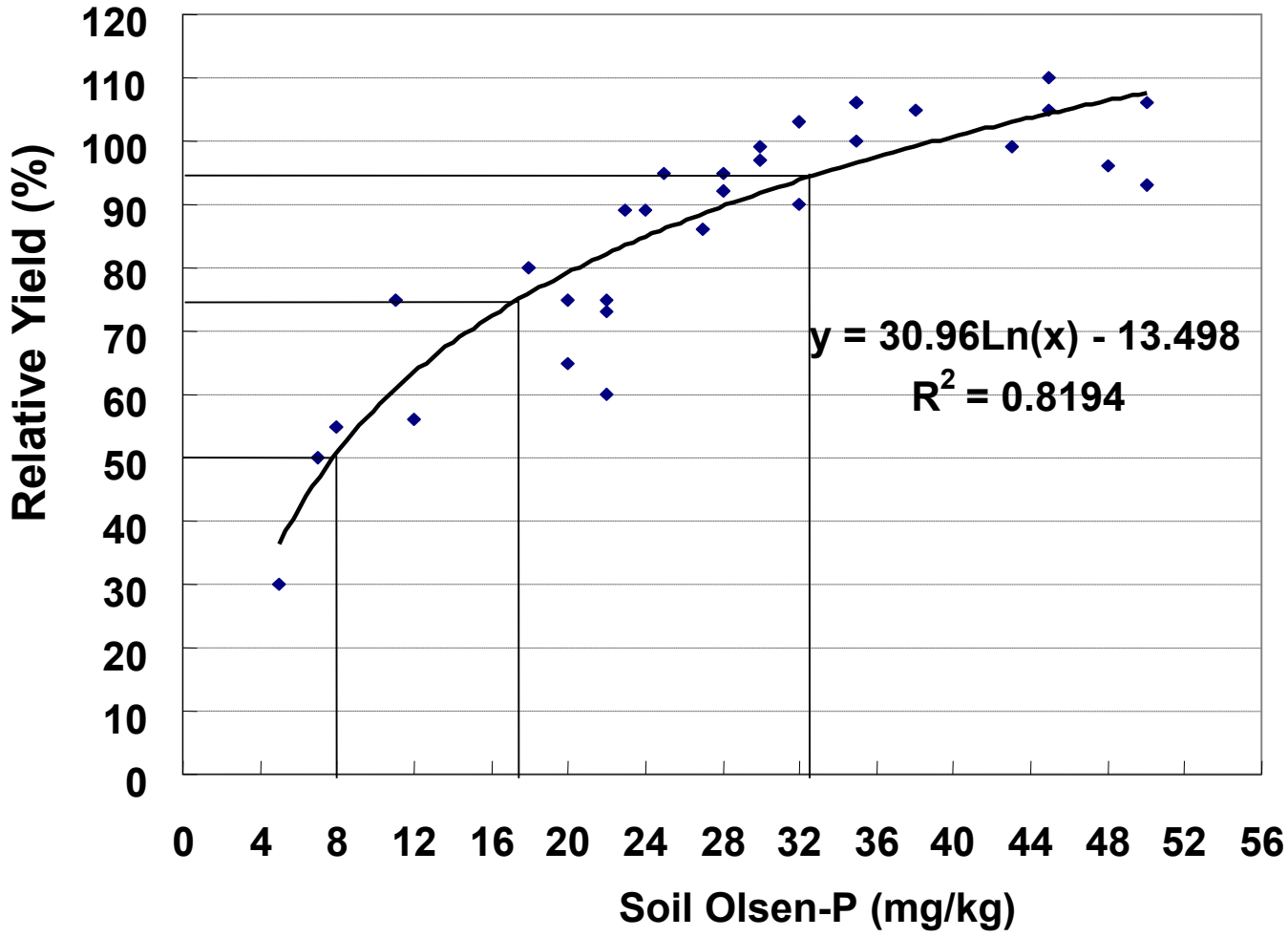
Data from Tang (2004); Liu (2004，2005)，et al

Open field

Data from Cai, 1997

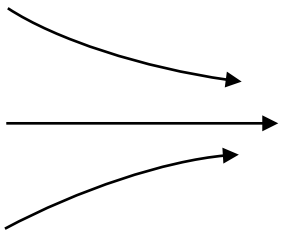
Soil index for P (or K) recommendation

(Example: Correlation between relative yield in the control plot without P supply with soil available P level)



Based on the responses of P and K fertilizers application, P and K recommendation "maintainence" can be used

Soil Olsen-P (mg/kg)		Soil exchangeable-K (mg/kg)	Index	P_2O_5/K_2O recommendation*
Open field	Greenhouse			
0~20	0~50	0~80	L	1.8-2.0 times of crop removal
20~60	50~120	80~150	M	1.3-1.5 times of crop removal
>60	>120	>150	H	0.8-1.0 times of crop removal

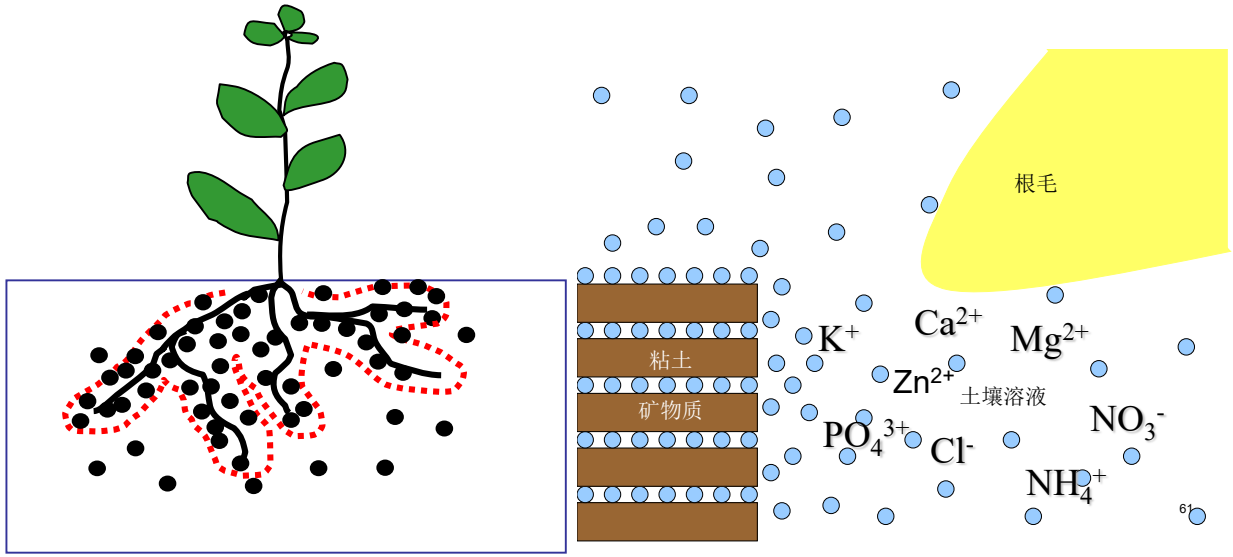


*Organic manure recommendation: open field 30-45 m^3/hm^2; protected field 60-90 m^3/hm^2）

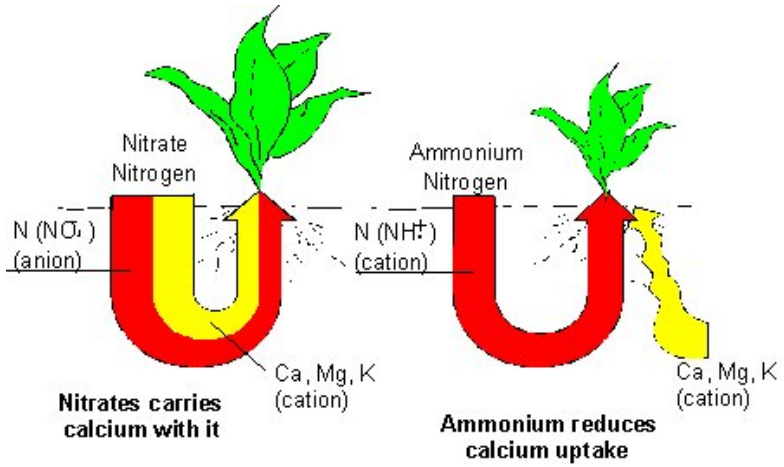
Key2: Relative proportion of nutrient supply in rootzone

Rootzone control and water soluble fertilizer use

- ✓It needs balanced nutrient supply.
- ✓Excessive NH_4^+ supply can cause the Ca^{2+}, K^+ deficiency
- ✓Excessive K^+ supply easily cause the Mg^{2+} deficiency
- ✓Excessive PO_4^{3+} supply easily cause the Zn^{2+} deficiency

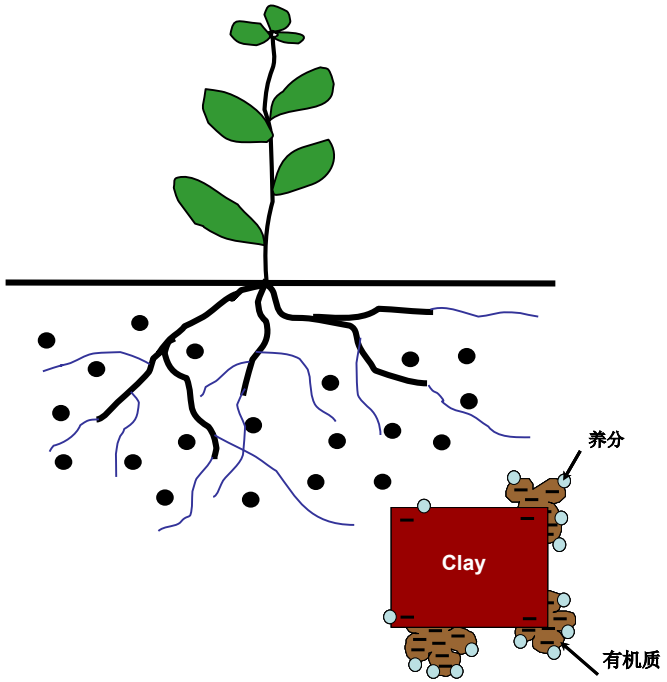


过量施用铵态氮造成K、 Ca、Mg的缺乏



Rootzone control and water soluble fertilizer use

Key3: Optimized soil environment in rootzone



- Select appropriate raw material and N form; Adjust the soil pH; Reduce fertilizer use and soil salinity
- Appropriate formula can promote crop root development, increase soil nutrient reserves, and reduce the possibility of nutrient loss
- Increase soil CEC and organic matter content in rootzone
- Reduce soil diseases, and straw return increase the microbial activity

Key4: Spatial match of root and water-fertilizer supply in rootzone

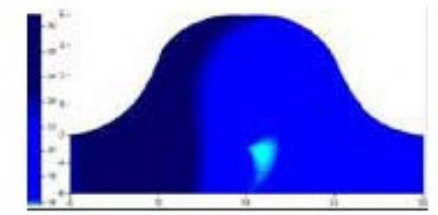
How to concentrate the effective water and nutrient on the root zone, and realize the time and space effectiveness?

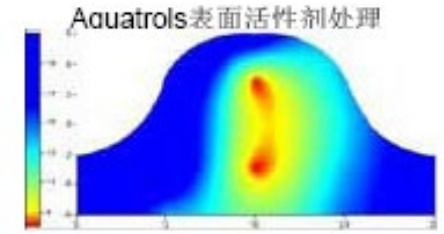
•IrrigAid

It should consider the use of IrrigAid in liquid water-soluble fertilizer formula, increasing irrigation area and achieving water retention is the key to improve nutrient use efficiency.

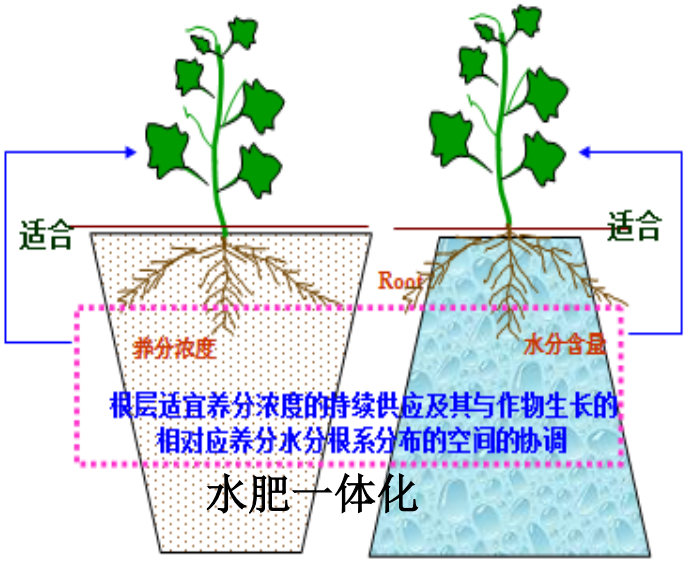
•Fertigation

Integrate irrigation and fertilizer, supply water and fertilizer for crops timely, precisely, accurately, and in balanced synchronous.





(Ren, Personal communication)



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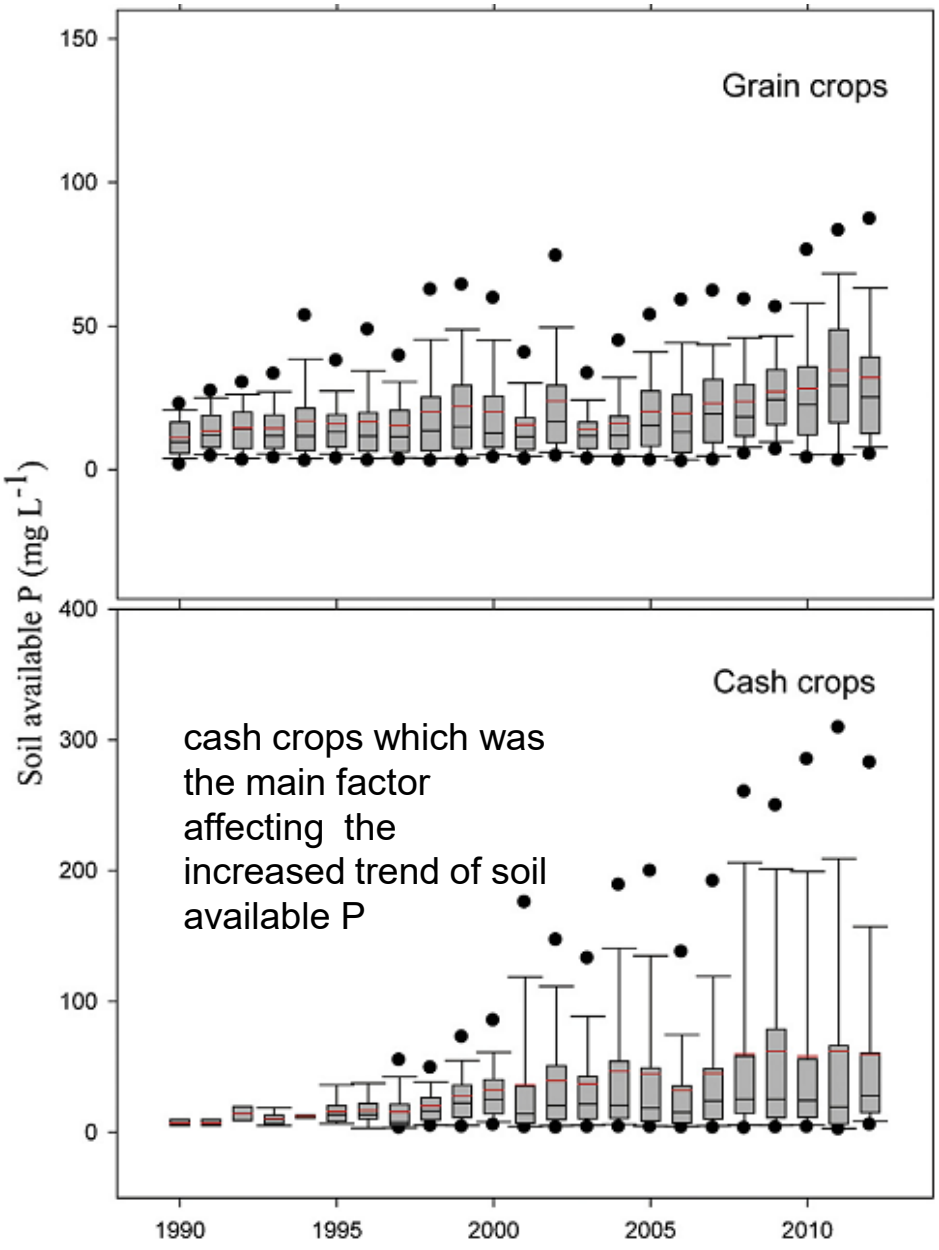
- Phosphorus fertilizer produced in China was 16.4 million t, accounting for 48.7% of the global production

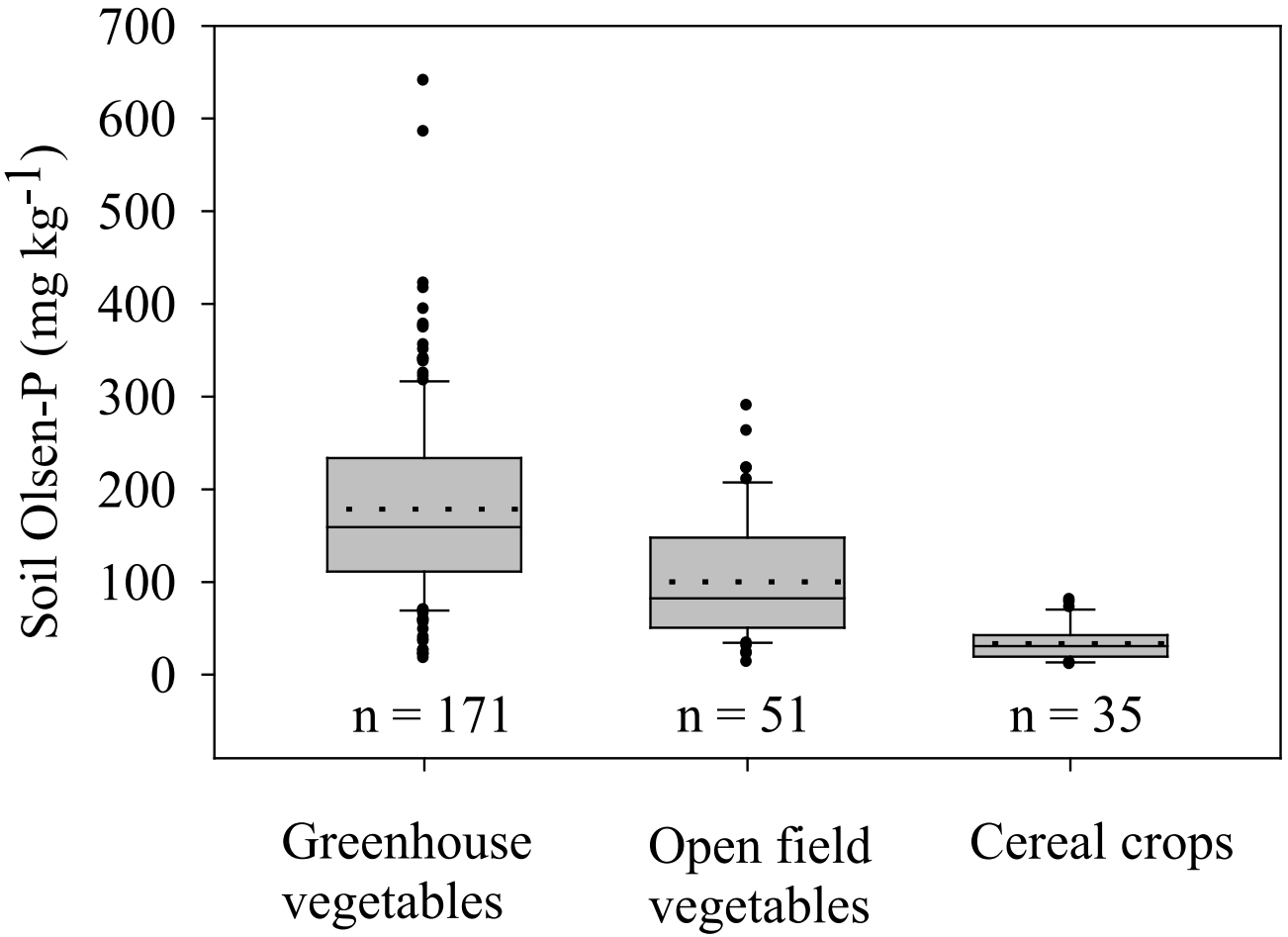
- Excessive fertilizer P input resulted in the high legacy P in soils of China

- Chinese government has promoted the projects of reduced chemical fertilizer application and encouraged organic manure utilization since 2015.



Trends of soil available P in China from 1990 to 2012. (Ma et al.2016)

Focusing on soil legacy P in vegetable fields



The P-imbalance in vegetable field

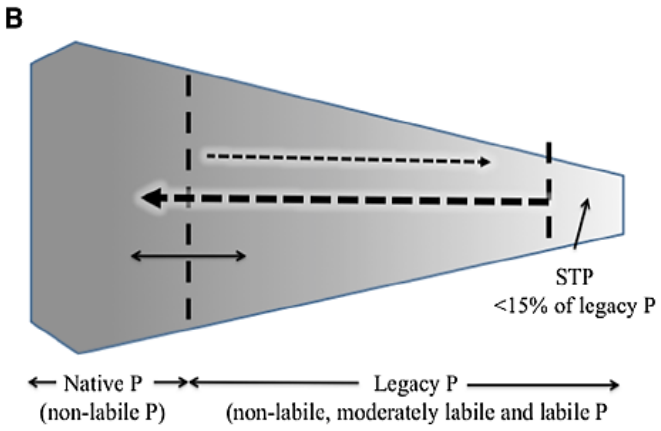
P application exceeded P removal by 13.0-fold in greenhouse and 4.7-fold in open field; Over 50%of applied P derived from manure

(Yan et al., 2013)

95% of protected-field existed the high risk of P mobility

- Agronomic threshold: 46-57 mg P kg^{-1} in open field; ~90 mg P kg^{-1} in protected field
- Environmental threshold: 50-60 mg P kg^{-1} (Jiang et al., 2008; Qin et al., 2010; Zhang et al., 2012; Wang et al., 2006)

Why high legacy phosphorus?



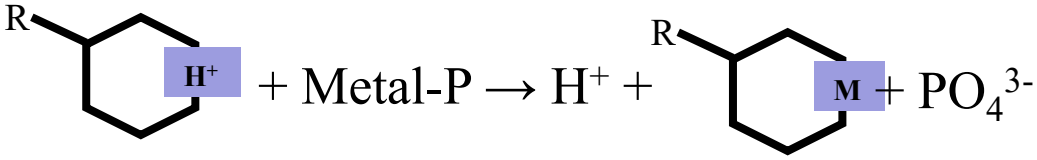
(Wither et al., 2014)

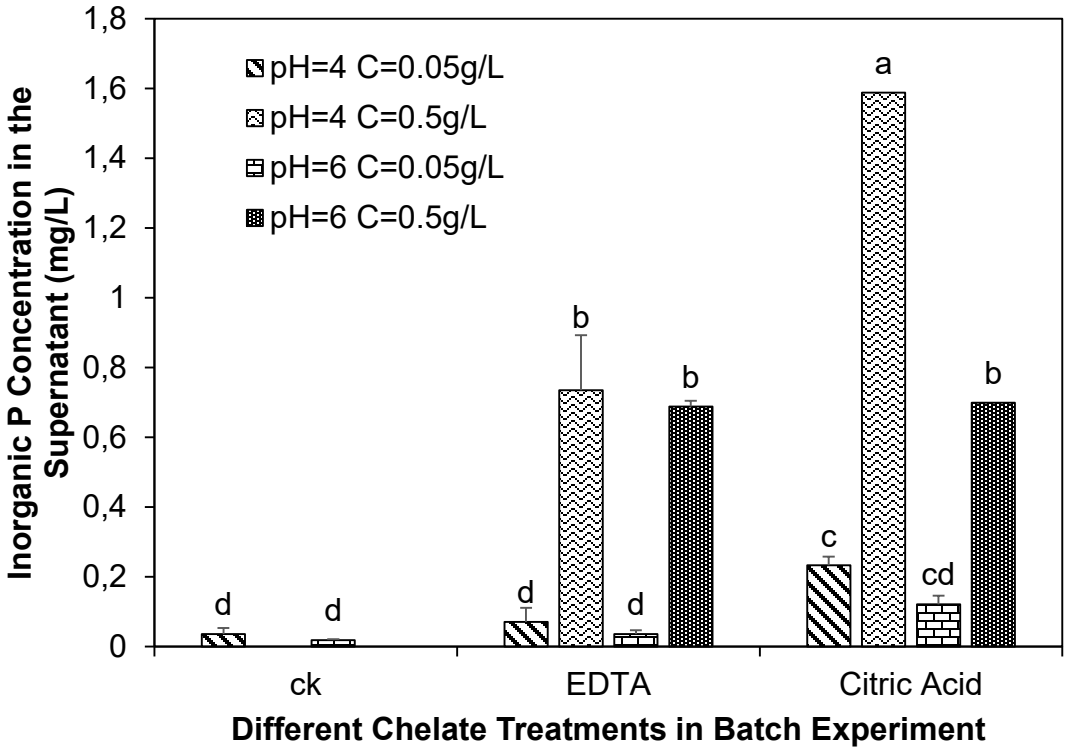
Soil P fertility

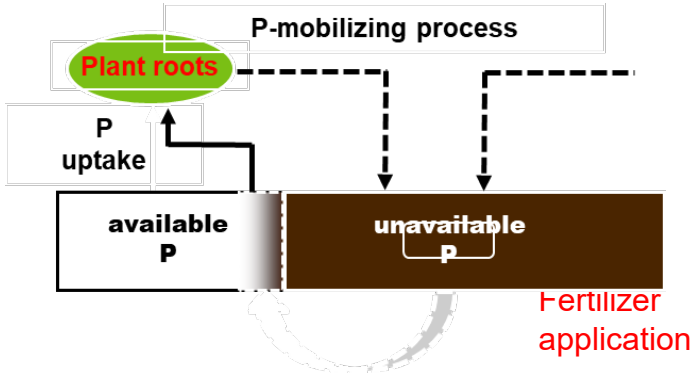
Eutrophication

The levels and forms of soil legacy P indicated the availability to crop or the mobility to environment

Chelates activated soil legacy P through combination/dissolution with phosphate metals in soil



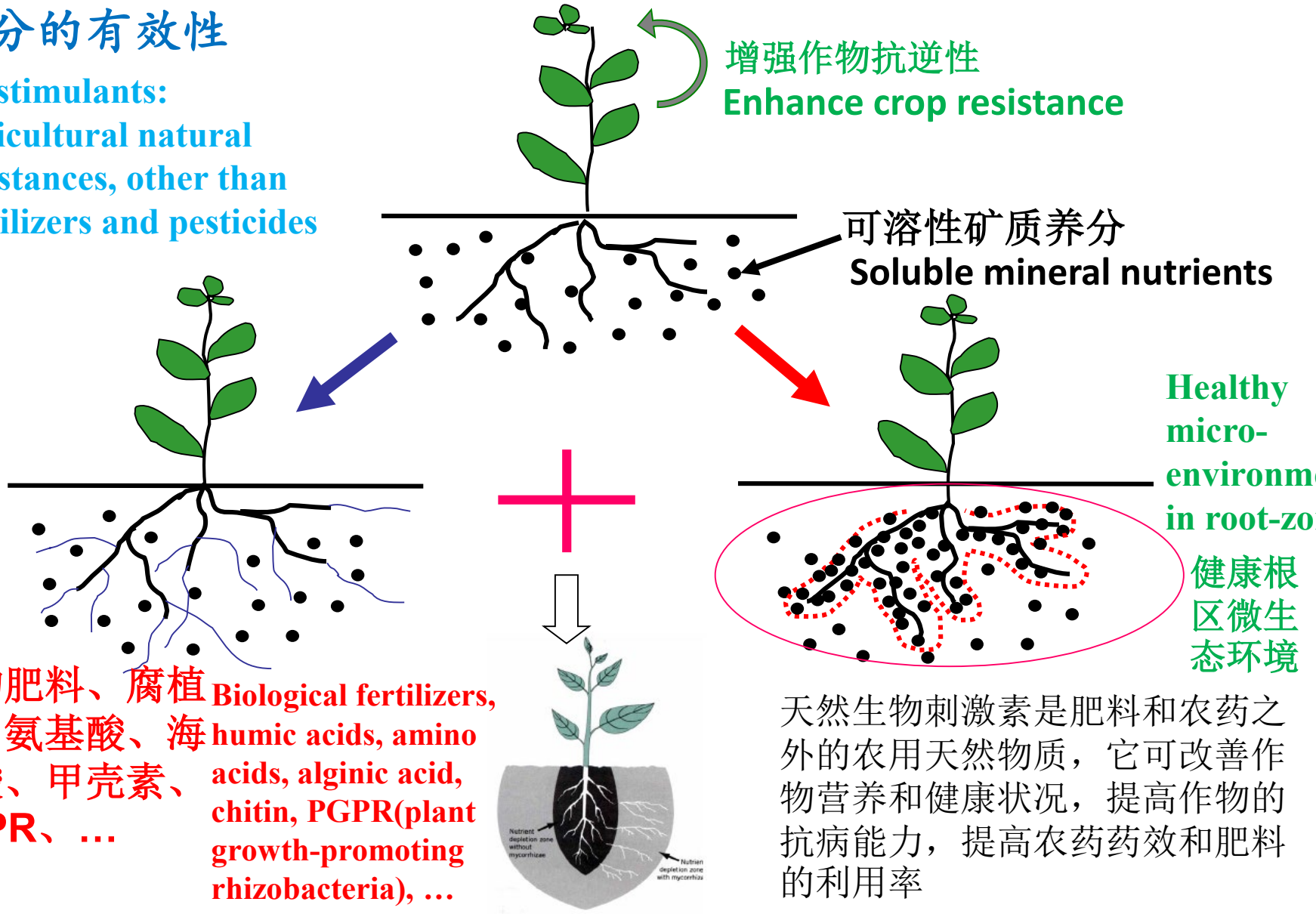




（Wang et al., Unpublished）

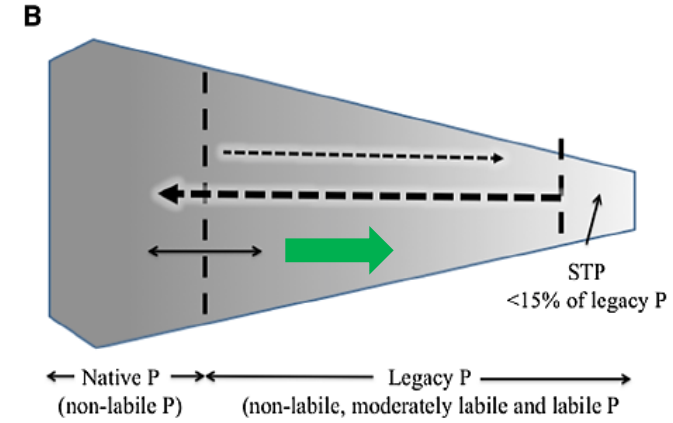
生物刺激素的促根和抗逆效应提高养分和水分的有效性

Biostimulants: agricultural natural substances, other than fertilizers and pesticides

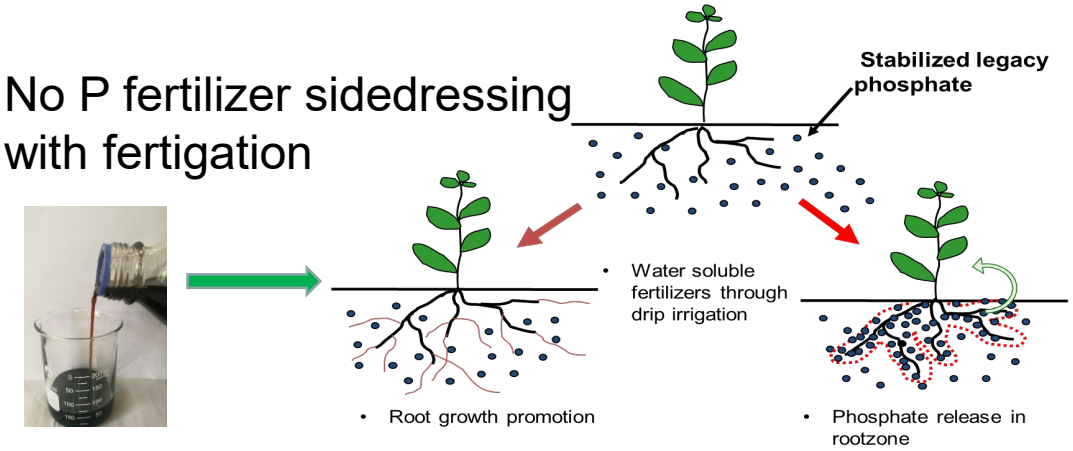


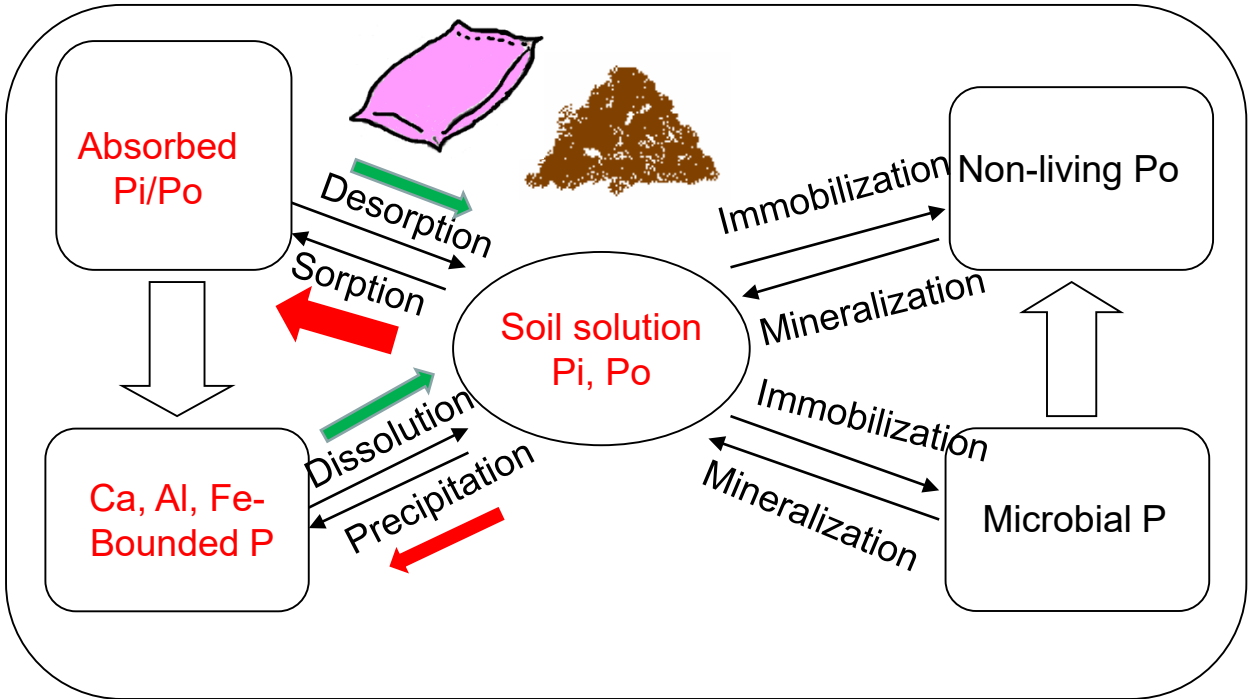
天然生物刺激素是肥料和农药之外的农用天然物质，它可改善作物营养和健康状况，提高作物的抗病能力，提高农药药效和肥料的利用率

Increasing rootzone P availability through fertigation accompanied strategy to utilize legacy P in soil

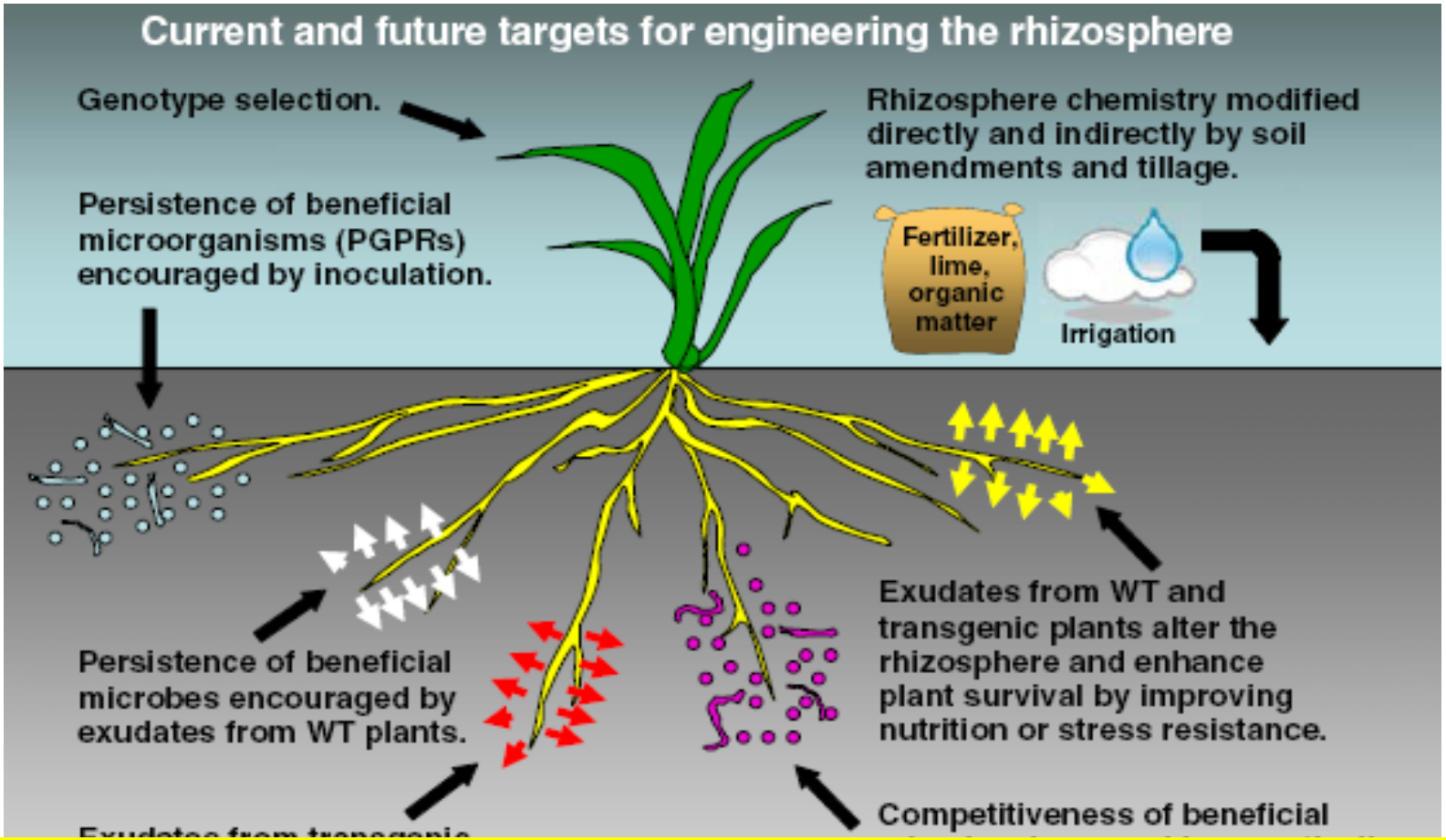


No P fertilizer sidedressing with fertigation





Biologically active substances to stimulate root growth and/or chelating metals i.e. amino acid fulvic acid, and citrate were selected as synergistic component in liquid water soluble fertilizers for drip irrigation



促进根系发育，优化根系结构，改善土壤物理、化学和生物过程，提高土壤水分、养分资源利用效率

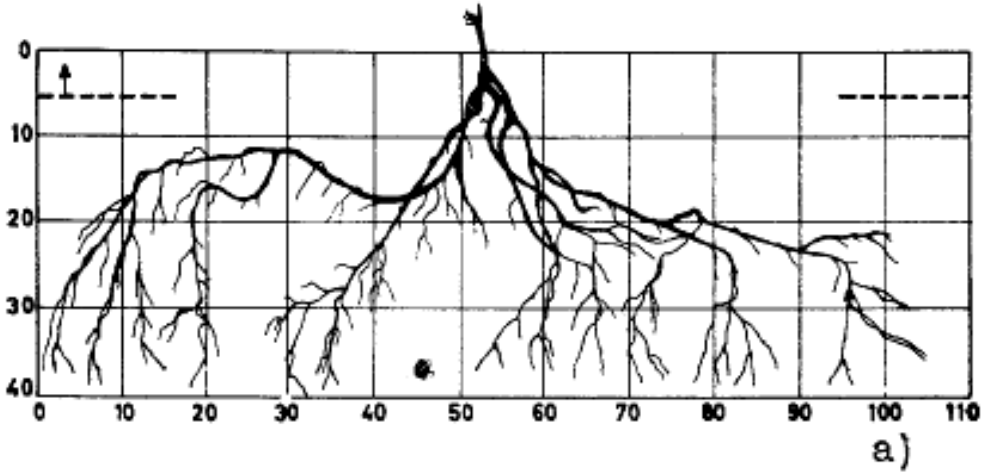
Fig. 1 Current and future targets for rhizosphere engineering The rhizosphere can be manipulated or engineered with agronomic practices, plant selection, soil inoculation or with biotechnology. Common practices such as soil tillage, fertilizer application or even irrigation can alter the chemistry of the plant-sol interface by changing aeration, root function or microbial communities. Plants with favorable roots traits that improve performance can be selected for by breeders. These traits could include exudates that increase nutrient accessibility, minimize stress or that encourage the persistence of beneficial micro-organisms. Biotechnology can be used to accentuate these useful traits or generate plants and micro-organisms with novel phenotypes that help plant survival. Transgenic plants and micro-organisms can be engineered to exude exogenous compounds that improve plant nutrition, repress pathogenic microbes and minimize the consequences of biotic or abiotic stresses

Peter R. Ryan.et al;2009

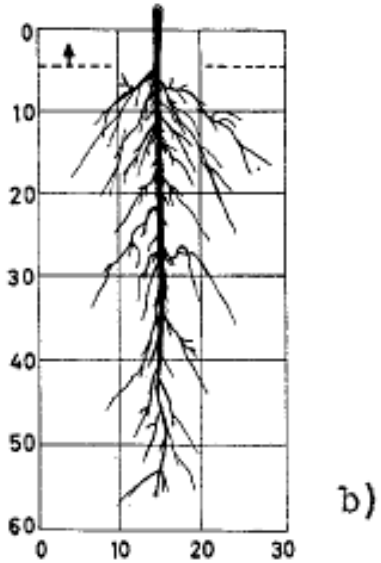
Factors on root growth in vegetable field:

caused by :

- low/ high temperature
- soil compaction
- root pathogens
- excessive nutrient stat
- soil secondary salinity



The physical root volume limitations may have caused secondary water or nutrient limitations



CARLOS A. M. PORTAS*

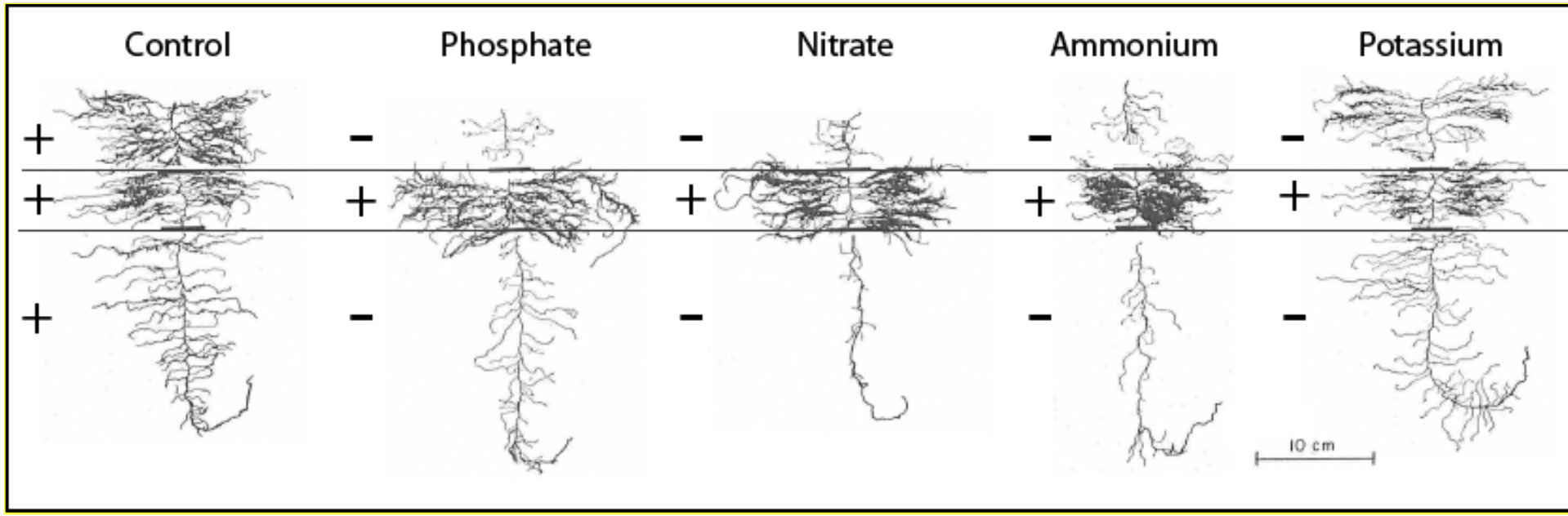
Plant and Soil 39, 507-518 (1973)

Fig. 6. Root system of melon 'Tendral'. (Values indicate *cm*).
a) Last sampling, At soil, irrigated
b) Last sampling, Pag soil, not irrigated. (deep, clay-loamy)
--- Hilling

Select formula:promote root and improve nutrient absorption
以促根和提高养分吸收为目标的多功能配方筛选

Localized supply of PO_4^{2-}, NO_3^-, NH_4^+, or K^+ and the architecture of barley root growth

供应PO_4^{2-}, NO_3^-, NH_4^+, 或 K^+ 时大麦根系结构

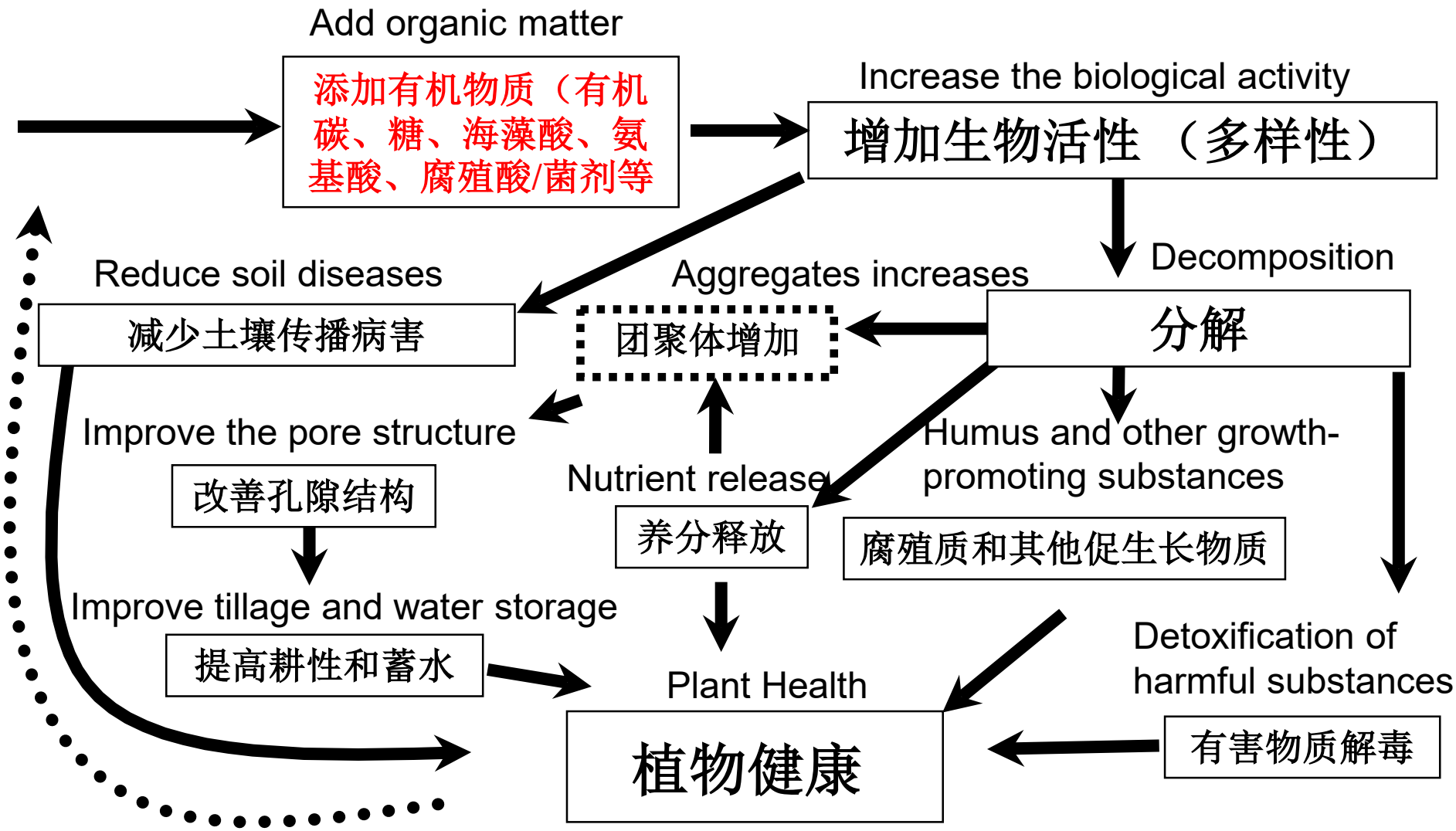


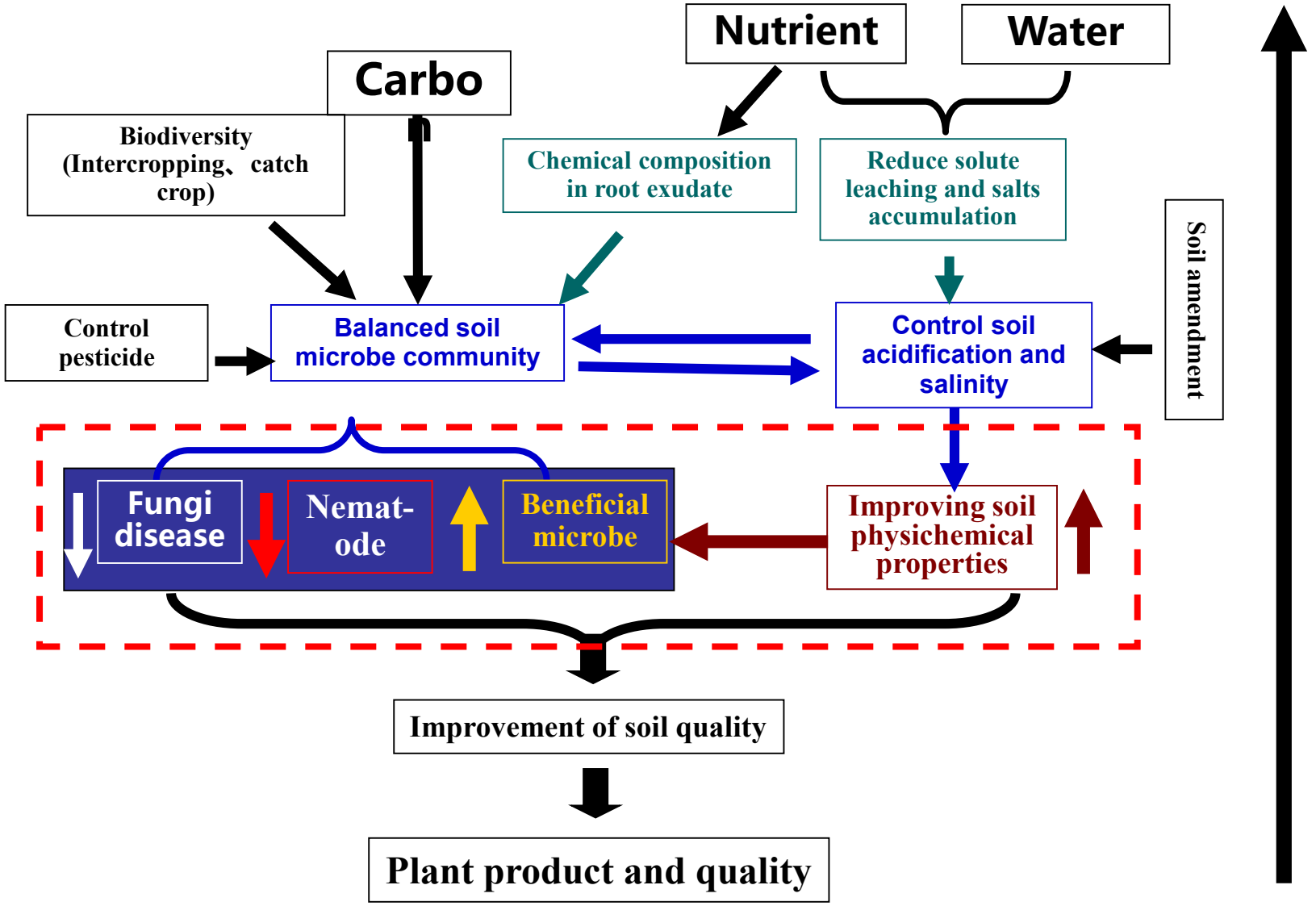
+ - portion of root system receiving complete nutrient solution
根系统的一部分吸收到完全营养液

- - Part of the root system receiving the solution deficient in specified nutrient
根系统的一部分吸收到缺乏某种营养的营养液

Drew (1975) New Phytol. 75 : 461-478

Biostimulant materials for functional liquid WSF
适用于功能型液体水溶性肥料 的生物活性物质





Strategies to improve greenhouse soil quality and productivity

Content

1. Bottle neck in high use efficiency of water and fertilizer in greenhouse vegetable production
2. Fertigation: basic demand to improve high UE of water and fertilizer
3. High efficient Utilization of water and fertilizer: Soil health and crop health
4. Summary

Innovative product and related techniques

- **High efficiency**: Meeting crop demand, time and labor saving, high efficiency;
- **Complex**: the inorganic complex; organic and inorganic complex; bio-organic compound; pesticides, hormones and herbicides compound
- **Wide-function:** Soil quality, root growth and seedling health, weeding-cleaning, flowers and fruit;
- **Low-carbon**:reduce greenhouse gas emissions.


Thanks for
your attention