Sustainable fertilization of vegetable crops

Training for farmers using manure in vegetable crops

2021

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Aim of the training

To learn how to implement a sustainable fertilizer schedule including cattle manure in vegetable crops

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Authors:

Herman de Putter
Wageningen Plant Research

Nikardi Gunadi
Indonesian Vegetable research Institute

Witono Adiyoga
Indonesian Vegetable research Institute

Deni Suharyono

Marion de Vries
Wageningen Livestock Research

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Foreword

Vegetables are increasingly recognized as an important component in food security and nutrition programs. Vegetables are a source of vitamins, minerals and fiber that are needed for health. Vegetables are generally cultivated intensively by small-scale farmers.

The high risk of crop failure and limited access to best practice information often encourage farmers to use inputs (e.g. fertilizers) excessively. This may not only have the consequences of causing economic inefficiency for farmers, but also pollution of the environment.

This module is designed to meet the needs of agricultural/animal husbandry extension workers and vegetable farmers regarding information on good practices on inorganic and organic fertilizer use. The module is prepared with the objectives of enabling trainees to (a) know the differences between various types of organic/manure fertilizers; (b) know the content of nutrients available in the soil;

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Foreword

(c) know the required nutrients for plants, (d) understand the plant nutrients absorption; and (e) determine the right amount of organic and inorganic fertilizers as required by the plant. This module can be used as a material for either training of trainers (TOT) or training of farmers (TOF). Most of the materials were designed based on the results of NutRecycle project (research cooperation between Wageningen University Research, the Netherlands; Indonesian Vegetable Research Institute; and North Bandung Cattle Breeders Cooperative).

Hopefully, this module can be useful not only for farmers, but also for agricultural extension workers in developing sustainable vegetable farming in West Java.

Bandung, October 2021

Kepala Dinas Ketahanan Pangan dan Peternakan Provinsi Jawa Barat,

Ir. H. Jafar Ismail, MM.

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Background

- This training was developed in the framework of the project 'Closing Regional Nutrient Cycles for low-emission Agriculture' (NutReCycle), which was a collaboration between Wageningen University and Research, IVEGRI, and the dairy cooperative KPSBU in Lembang. The NutReCycle Project was executed between 2018-2021 and aimed to increase the utilization of nutrients in locally produced cattle manure and thereby reduce environmental pollution in Lembang Regency. This project was funded by the government of The Netherlands, through CGIAR Research Program CCAFS.

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Disclaimer

- The material and information in this training is developed and compiled according to the authors best knowledge. However, the use of this material and information is at the users risk and no responsibility will be taken by the authors.

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Required nutrients by vegetable crops

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Healthy vegetables

- Vegetables are healthy because they contain a lot of nutrients and vitamins
- With harvest products contain these and are " taken away" or removed from the fields
- Taken away means: nutrient content in the field is reduced
- Let's take a closer look at the nutrients needed for crop growth first.

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Crop nutrient requirements

- Just to start.....
  - Can you mention which nutrients are required by a crop?

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Needed nutrients

- Macro elements
  - Nitrogen: N
  - Phosphorus: P
  - Potassium: K
  - Magnesium: Mg
  - Calcium: Ca
  - Sulphur: S
- Trace elements
  - Iron: Fe
  - Zinc: Zn
  - Molybdenum: Mo
  - Manganese: Mn
  - Cupper: Cu
  - Boron: B
- Hydrogen: H
- Carbon: C
- Oxygen: O

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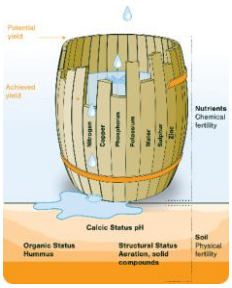
Different nutrients have different roles.

- Production of sugars/photosynthesis (N, Mg, S, P)
- Growth (N)
- Root formation (P)
- Health (K and Ca)
- Cell strength (Ca)
- Quality of fruits (Ca and K)
- Transport (K and P)
- Assisting with uptake of water and nutrients (K, P, micro nutrients)
- Flowering and fruit set (K and micro nutrients)

All nutrients are needed, lack of one can not be compensated by another one

In this situation lack of Nitrogen is causing yield loss

Adding more potassium does not improve yield!



Questions?

Sources of nutrients

What are sources of supply?

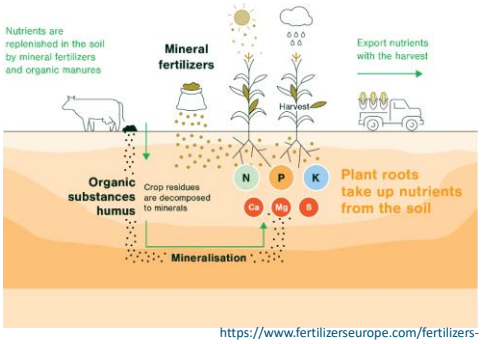
- With vegetable products quite some nutrients are "taken away" from the field.
- Need for nutrients to supply to the plants
- Quick round of asking farmers' ideas where plants can get the nutrients from.

Possible sources

- Fertilizers
  - Organic and inorganic
- Soil
  - Contains a lot of nutrients
    - Freely present in soil
    - Attached to or included in mineral particles
    - Organic matter
- Water (rain and irrigation)
- Air (deposition)

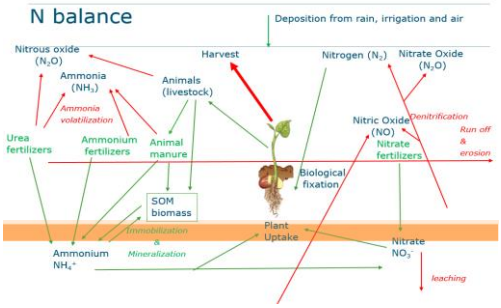
Nutrient inputs and outputs

Inputs	Outputs
Organic fertilizers	Harvested product
Chemical fertilizers	Volatilization losses
Crop debris	Leaching losses
Deposition	Erosion and run off losses



https://www.fertilizerseurope.com/fertilizers-in-europe/balanced-plant-nutrition/

Nitrogen cycle



Questions?

Chemical Fertilizers

Can you name chemical fertilizers?

- Name?
- What is in it?
- How much?

Chemical fertilizers

- Diverse
  - Ammonium sulphate, Urea
  - SP 36
  - NPK compound

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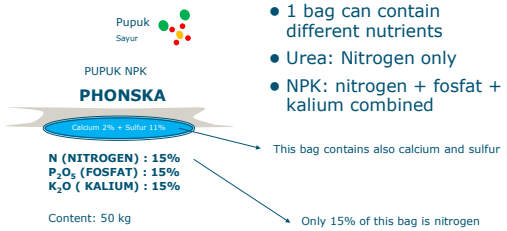
Fertilizers and nutrients



- Fertilizers do contain nutrients
  - 1 bag can contain different nutrients
  - Urea: Nitrogen only
  - NPK: nitrogen + fosfat + kalium combined

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Example of Chemical fertilizers

Fertilizer	N %	P2O5 %	K2O %	S %	CaO %	MgO %
Ammonium sulphate	21	0	0	24		
Urea	46	0	0	0		
SP 36	0	36	0	11		
NPK Phonska	15	15	15	9		
NPK Mutiara	16	16	16			
KCL/MOP			60			
Calcium Nitrat	15.5				26	
Kalium Nitrat	13		46			
Magnesium Sulphate				13		16

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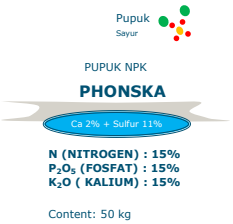
Fertilizers and nutrients



- In groups:
  - How much kilo Nitrogen is in this bag?
  - And how much Fosfat and Kalium?
  - How much kg Calcium is in this bag?
  - How many bags do you need to apply 300 kg Nitrogen on your field?

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Questions?

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Current fertilizer practices

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What is the current practice?

- Please discuss on:
  - Which fertilizers are used?
  - When do you apply fertilizers?
  - Which organic fertilizer do you apply?
  - How much?
  - How do you determine how much is needed for your crop?
  - Finally, do you think you have the best strategy already? If not, what do you need?

Current practice observed at farms

- Use of manure
  - Mainly chicken manure (postal)
  - Produce from dairy cows
    - Vermicompost
    - Compost
    - Heap manure
  - 1x per year to each time per new crop

Current nitrogen quantities (kg/ha)

Farm	Broccoli	Cauliflower	Petsai	Horenzo	Lettuce	Pakchoy	Siomak	Tomato	Chilli
A		663			57				
B						150	446		
C		492							
D				150					
E					88				269
F	268		105					222	
Average	268	578	105	150	72	150	446	222	269
equivalent Urea amount	582	1256	228	326	156	326	970	483	585

To put it in perspective the amount of urea with a same nitrogen amount is presented too

Any comments from the participants on these amounts?
Let's vote.

Current applied nitrogen quantities (kg/ha)

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A		663			57				
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F	268		105					222	
Mean	268	578	105	150	72	150	446	222	269

Nutrient supply and costs in half a year

Farm	Costs (IDR/ha)	Manure (t/ha)	N	P_2O_5	K_2O	CaO	MgO	S
A	3,415,820	41.1	727	266	200	702	250	291
B	1,741,728	41.1	571	406	346	537	215	0
C	1,253,771	6.8	157	108	153	120	65	71
D	1,317,750	19.8	449	373	298	364	113	0
E	443,156	12.5	142	106	125	58	144	0
F	5,124,000	33.4	638	778	369	162	451	460
Average	2,216,038	25.8	447	340	249	324	207	137

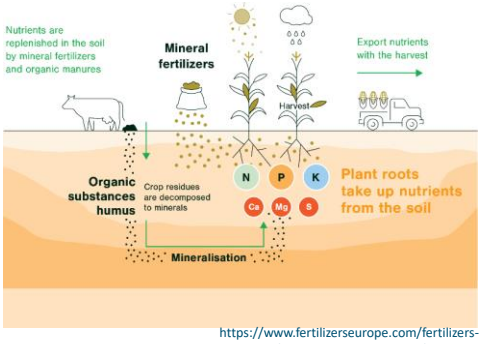
Variation between farms in manure use and total nutrient quantities

Questions?

Nutrient removal with vegetables

Principle

- With harvest product is taken away from the field
  - Product contains nutrients
  - Nutrients are taken from the soil by the plants
  - The crop contains significant levels of nutrients at harvest
  - Crop product is harvested and taken from the field to the market
  - Nutrient level in the soil is now lower
- If nothing is added soils will be depleted after time



https://www.fertilizerseurope.com/fertilizers-in-europe/balanced-plant-nutrition/

Content of nutrients in crops of pilot farmers (g/kg product)

Crop	N	P	K	Ca	Mg	S
Broccoli	2.8	0.4	2.9	0.6	0.2	0.5
Cauliflower	2.6	0.4	2.4	0.8	0.1	0.3
Chinese cabbage (Petsai)	1.8	0.3	2.3	0.6	0.1	0.5
Horenzo	3.2	0.4	6.5	1.2	0.8	0.3
Lettuce	1.3	0.2	2.3	0.4	0.1	0.1
Pakchoy	1.3	0.3	2.7	0.7	0.1	0.4
Siomak	1.7	0.3	3.4	0.5	0.2	0.1
Tomato	0.3	0.1	1.4	0.1	0.1	0.1
Chilli (baby pepper)	4.7	0.6	4.4	0.6	0.2	0.5
Average	2.2	0.3	3.5	0.7	0.3	0.3
Rice white long	11.4	1.2	1.5			
Corn sweet raw	5.2	0.9	2.7			

Rice and sweet corn data from USDA Food data https://fdc.nal.usda.gov/

Vegetable crops relative lower in P than staple crops
Low P demand

Yield of crops grown by pilot farmers

Crop	Yield (kg/ha)
Broccoli	7,655
Cauliflower	13,549
Chilli (Baby Pepper) (Intercropping With Tomato)	1,029
Chinese Cabbage (Petsai)	4,244
Horenzo	11,000
Lettuce	7,886
Lettuce (Intercropping With Chilli)	16,071
Pakchoy	18,500
Siomak	7,659
Tomato	18,327
Tomato (Intercropping With Chilli)	15,257

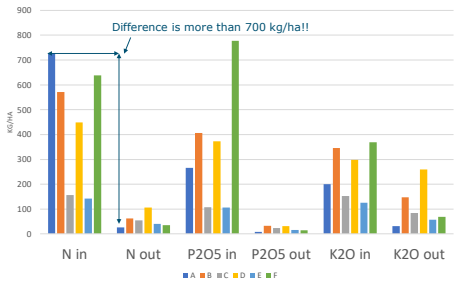
Nutrient Removal (kg/ha) = nutrient content (g per kg) x yield (kg per ha)

Results of pilot farmers

Farm	N	P_2O_5	K_2O
A	26	8	31
B	62	33	147
C	55	24	84
D	106	32	259
E	41	16	57
F	35	15	69
Average	**54**	**21**	**108**

- Output (removal) of nutrients with harvested product in kg/ha

Balance: compare IN with OUT



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Soils

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Soil characteristics

- Soils are the source and medium for nutrient uptake by plants
- Presence of nutrients is not equal to availability
- pH and organic matter
- Soil samples are providing info on nutrient availability

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soil as a source of nutrients

Uptake influenced by: pH, Balance, Quantity, Moisture

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Participants opinion on their soils

- What can you tell about the soil of your field?
  - Is it fertile?
  - Is it a nice soil? And if yes why?
  - How do you take care of your soil?
  - Do you have information about nutrient content and pH of your field?

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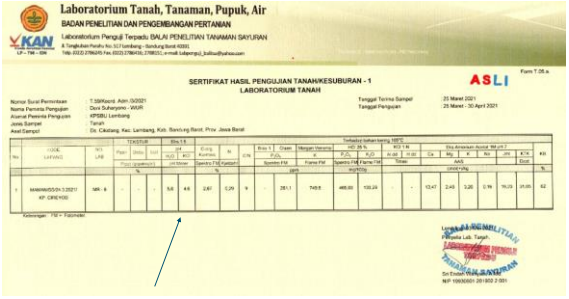
Example of a soil sample



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Kriteria penilaian hasil analisis tanah

	Sangat rendah	Rendah	Sedang	Tinggi	Sangat tinggi
C-org (%)	< 1	1 - 2	2 - 3	3 – 5	> 5
N – total (%)	< 0.1	0.1 – 0.2	0.2 – 0.5	0.5 – 0.75	> 0.75
P2O5 (Bray)	< 5	5 – 10	11 – 15	16 – 20	> 20
P2O5 (Olsen)	< 10	10 - 20	21 - 40	41 – 60	> 60
K2O (mg/100g)	< 5	5 - 16	17 - 24	25 – 40	> 40

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Results of 6 Soil samples Lembang region

- Taken at vegetable farms using manure

Farm	pH KCl (1:5)	C-Org %	N Tot % (Kjeldahl)	P2O5-Bray (ppm)	P2O5-Olsen (ppm)	K2O mg/100 g
A	4.1	8.1	0.7	86		51
B	4.9	2.5	0.3		353	749
C	4.6	7.4	0.7	130		98
D	4.6	6.2	0.7	87		74
E	4.6	2.7	0.3		281	133
F	4.9	3.8	0.4		1183	104

Acid soils; On average high; Very high content

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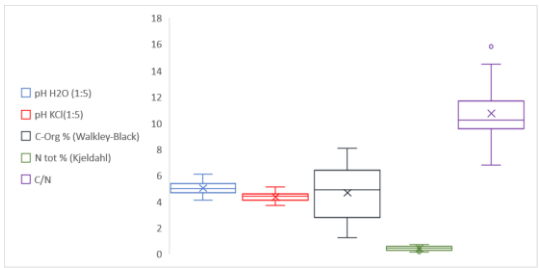
Results of 29 samples taken around Lembang



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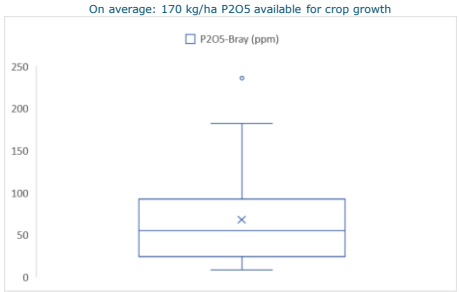
Phosphate status of soils

On average: 170 kg/ha P2O5 available for crop growth



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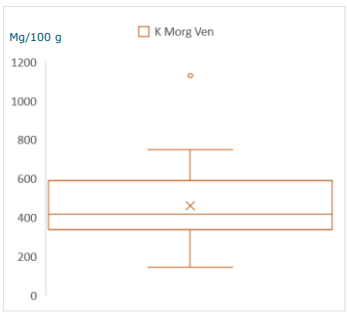
Potassium status of soils

- Average:460
- Range:
  - 340
  - 600



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Blossom end rot

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Conclusion

- Soils are high in nutrients
  - Especially P and K
- Soils contain a lot of organic matter
- Soil tend to be acidic
  - Lot of P not available

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Questions?

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Manure use in vegetables

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Short group discussion

- How much used?
- What is used?
- For what reasons is manure used?
  - Advantages
  - Disadvantages
- How are rates determined?
  - How do you know how much to apply/use?
  - Differentiation per crop and field considered?
    - Why not or why yes?

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Manure types

- Source from animal origin
  - Chicken
  - Cow
  - Goat
- Mixed and processed
  - With or without bedding material (straw, rice husk etc)
  - Composted or not

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Benefits

- Adding more to the soil than just one nutrient (e.g urea only applies nitrogen)
  - A range of nutrients is added including trace nutrients
- Adding organic matter to the soil
  - Improves water balance in the soil
  - Acts as a buffer for nutrient supply
- Slow release of nutrients (nitrogen and phosphate)
- Using manure reduces the chemical fertilizer use
  - Less impact on pH decline

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Disadvantages

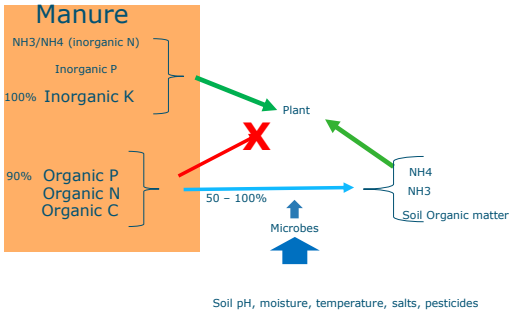
- Low nutrient content (bulky)
  - High volumes of manure needed
- N-P-K ratio not in line with plant requirement
- Unknown and variable nutrient content
  - Hard to assess the required quantities
- Risks of importing unwanted elements
  - Weed seeds
  - Pathogens
  - Heavy metals (lead, cadmium)

Typical content of manure types

Types	DM%	Ntot (%)	N-NH3	P (%)	K(%)	N-NH3 % in tot N
Dairy manure: manure heap (solid manure)	39.3	0.72	0.03	0.19	0.27	3.8
Diary manure: compost	42.4	0.85	0.03	0.33	0.43	3.7
Dairy manure: vermi-compost	35.1	0.80	0.03	0.41	0.38	4.2
Postal (broiler chicken manure with rice husks)	70.8	1.99	0.20	0.58	1.65	9.8

% based on wet weight of the manure product

Manure: from organic to inorganic



Release of nutrients from manure

- Total Nitrogen = N-mineral + N organic
  - Manure contains immediately available N or N-mineral and slowly release of nitrogen from N organic
  - About 10 – 20% is immediately at application
  - In about 60 days 50 % of the total Nitrogen has been released
- P is mostly fixed in manure and is released slowly
  - In about 60 days 30 to 50% of the total P has been released
- K is for 70-80% immediately available at application date.
  - In about 60 days 100% of the K has been released

Consider the after supply in the next crop

- From manure applied in one crop about 10 to 20% of the nutrients will only become available in the next crop.

How much needed? (or possible to use)

- Crop need (example by approximates):
  - 250 kg/ha N
  - 75 kg/ha P2O5
  - 300 kg/ha K2O
- Crop duration 90 days
- Vermicompost
  - 0.8 % N -> 80% available = 0.64%
  - 0.4 % P2O5 -> 80%available = 0.32%
  - 0.4 % K2O

How much manure is possible

- Nitrogen need is 250 kg/ha
- 1 ton vermicompost supplies: 1000/100 * 0.64 =
  - 6.4 kg N
- 250 / 6.4 = 39 ton vermicompost
- 1 ton vermicompost supplies 1000/100 x 0.32 =
  - 3.2 kg P2O5
  - 39 ton x 3.2 = 125 kg P2O5 per hectare
- Crop need is: 75 kg p2O5
  - So with 39 ton 50 kg P2O5 too much is applied
  - Limit is 23 ton vermicompost, more will apply more P2O5 than advised.

Example prices of manure

Product	IDR/kg
Compost/heap manure 1:5	300 – 850
Heap compost	100 – 150
Postal	350 – 1,000
Vermicompost	350 – 1,000

Per hectare about 5 to 10 ton is needed

Example: 10 t/ha vermicompost at 500 IDR/kg will cost then 5,000,000 IDR/hectare

Effect of manure on organic matter content of soils

- Each year soil organic matter decreases
  - Decomposing of organic matter by organisms
  - Release of nutrients
- Manure consist of different solids
  - Fast degradable matter
  - Slow degradable matter
- Only the slow degradable part will add to soil organic matter
- About 30 tons/hectare is needed to maintain a same level with manure having a dry matter of at least 25%

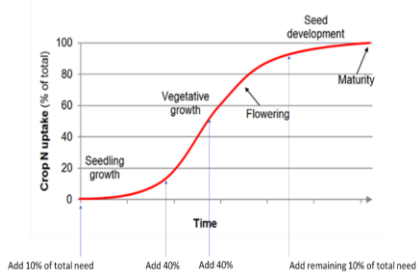
Questions?

Fertilization strategies

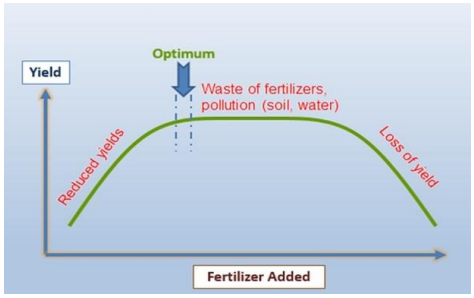
Split applications

- Split applications
  - At planting
  - Side dressings 2 to 3x per crop season
- Why are they recommended?
  - Short enquiring with farmers
  - Write down answers and formulate conclusion

Uptake of nutrients



Too low or too high is not good!



Fertilization: summary

- Adding fertilizers should be in line with the balance!
  - Too much:
    - Loss of money!
    - Pollution of environment
  - Not enough:
    - Loss of money!
    - Lower yield

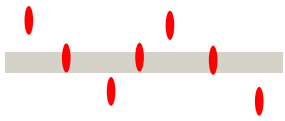
How to determine fertilizer rates

Use of soil samples

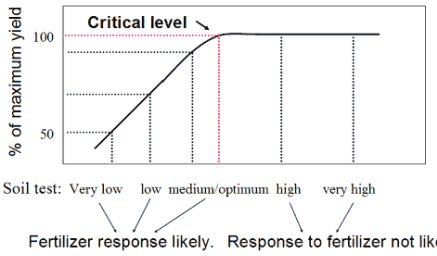
- Take a soil sample
- Analyse content by lab
- Evaluate levels of nutrients
- Link fertilizer advice to levels

How to take a soil sample

- 1 sample per hectare (2 hectares means 2 samples)
- 20 cores per hectare
- Core depth till root depth (20 -30 cm deep)
- Take the cores in a zig-zag pattern



Soil test classifications indicate whether or not adding a nutrient is likely to result in a yield increase.



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Ivegri develops recommendations per crop

Fertilizer (Urea, SP-36 and KCl) doses based on nutrient status (low-L, medium-M and high-H) for Cabbage grown in Andisol.

Nutrient status		Single Fertilizer				Compound Fertilizer	
Phosphorus	Potassium	ZA	Urea	SP-36	KCl	NPK 15-10-12	ZA
		..... kg/ha				..... kg/ha	
L	L	100	150	225	150	525	100
	M	100	150	225	100	525	100
	H	100	150	225	75	525	100
M	L	100	150	185	150	450	100
	M	100	150	185	100	450	100
	H	100	150	185	75	450	100
H	L	100	150	150	150	350	100
	M	100	150	150	100	350	100
	H	100	150	150	75	350	100

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Fertilizer (Urea, SP-36 and KCl) doses based on nutrient status (low-L, medium-M and high-H) for Hot pepper grown in Andisol

Nutrient status		Single Fertilizer				Compound Fertilizer	
Phosphorus	Potassium	ZA	Urea	SP-36	KCl	NPK 15-10-12	ZA
		..... kg/ha				..... kg/ha	
L	L	150	130	165	185	400	150
	M	150	130	165	165	400	150
	H	150	130	165	150	400	150
M	L	150	130	150	185	350	150
	M	150	130	150	165	350	150
	H	150	130	150	150	350	150
H	L	150	130	130	185	300	150
	M	150	130	130	165	300	150
	H	150	130	130	150	300	150

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Fertilizer (Urea, SP-36 and KCl) doses based on nutrient status (low-L, medium-M and high-H) for potato grown in Andisol

Nutrient status		Single Fertilizer				Compound Fertilizer	
Phosphorus	Potassium	ZA	Urea	SP-36	KCl	NPK 15-10-12	ZA
		..... kg/ha				..... kg/ha	
L	L	185	200	525	300	1200	185
	M	185	200	525	250	975	185
	H	185	200	525	185	750	185
M	L	185	200	450	300	1200	185
	M	185	200	450	250	975	185
	H	185	200	450	185	750	185
H	L	185	200	400	300	1200	185
	M	185	200	400	250	975	185
	H	185	200	400	185	750	185

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Recommendation with Vermicompost from dairy manure

	Vermi Compost t/ha	Urea Kg/ha	SP36 Kg/ha	KCl Kg/ha
hot pepper	10	144	0	92
shallot	10	195	44	152
cabbage	10	141	8	27
potato	15	203	194	141

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Recommendation with compost from dairy manure (cow + chicken mix)

	Compost t/ha	Urea kg/ha	SP36 kg/ha	KCl kg/ha
hot pepper	10	140	16	84
shallot	10	191	73	144
cabbage	10	138	37	19
potato	15	203	81	57

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How to determine fertilizer needs without soil sampling?

- Crop removal as start
- Fertilizer efficiency
- Soil status
- Manure application till limiting nutrient
- Additional chemical fertilizer
- Split applications

Recommendation with vermicompost based on Nutrient balance

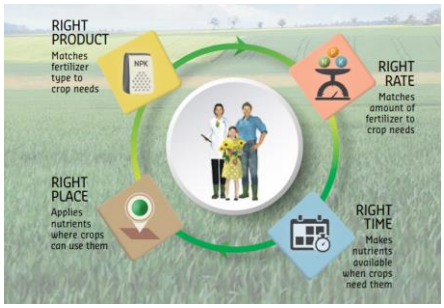
	Vermicompost	Urea	KCl
Broccoli	5	40	11
cauliflower	5	98	34
chilli	5	0	0
chinese cabbage	5	0	0
horenzo	5	119	153
lettuce	5	0	8
pakchoy	5	73	86
siomak	5	21	23
tomato	5	44	16

Recommendation with Compost use

	Compost	Urea	KCl
Broccoli	5	36	5
cauliflower	5	94	37
chilli	5	0	0
chinese cabbage	5	0	0
horenzo	5	116	147
lettuce	5	0	0
pakchoy	5	71	79
siomak	5	19	17
tomato	5	39	10

Questions

Remember the 4R's



https://www.fertilizerseurope.com/wp-content/uploads/2019/08/Fertilizer_Basics.pdf

Summary

- Do not apply more nutrients than the crop needs
  - Excess rates of organic and chemical fertilizers pollutes the environment and costs money
- Apply lime to increase the soil pH to improve the P uptake
- With reduced use of Urea and Ammonium the soil pH will also not drop further
- Dairy manure is a good source of supplying nutrients
- Dairy manure is an excellent source to maintain soil organic matter
- Avoid losses by incorporating the manure properly in the soil

Healthy food

For a nutritional vegetable dish nutrients are needed for a good crop

But..... All in balance