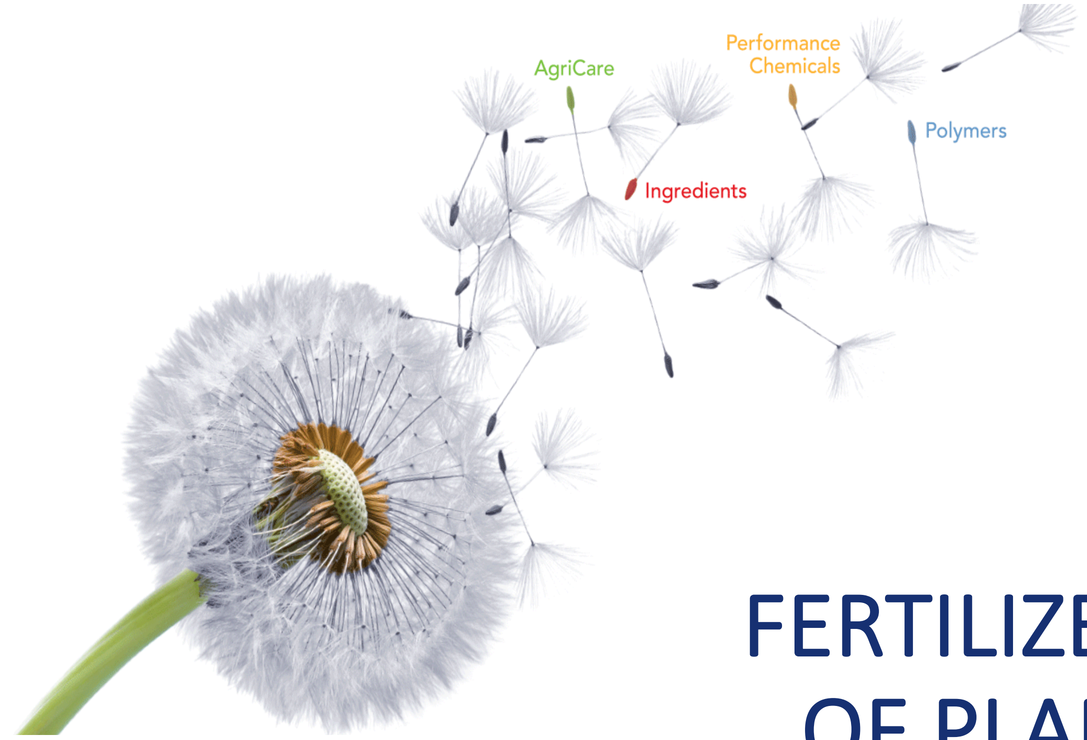

FERTILIZERS AS SOURCES OF PLANT NUTRIENTS

ALBERT HENG

MEOA - FERTILIZER LAB SEMINAR 2016

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"Discovery consists of seeing what everyone has seen, and thinking what no one has thought."

"創造包括了見眾人所見，思無人所想"

- Albert Szent-Györgyi
1937 Nobel Laureate

Topics:

- Introduction:
  - Essential and beneficial plant nutrients
  - Nutrient forms absorbed by the plant
- Fertilizers – types and classification
- Straight fertilizers that supply N, P, K & Mg, B, & S
- Multi-nutrient fertilizers - blends and compounds
- Stabilized fertilizers
- Slowr-release & controlled release fertilizers
- Conclusion

Essential Plant Nutrient Elements (17)

- Nutrient elements obtained from atmosphere and water through photosynthesis – H, C, O
- Nutrient elements obtained form the soil (mineral nutrients):
  - N, P, K, Mg, Ca, S ← Macro-nutrients (0.2-4.0% of plant tissue*)
  - B, Cu, Zn, Fe, Mo, Mn
  - Ni, Cl ← Micro-nutrients (0.1-200ppm; <0.02%*)

** Dry-matter basis*

- Beneficial or Functional nutrients e.g. Na, Si, Se, (Co)

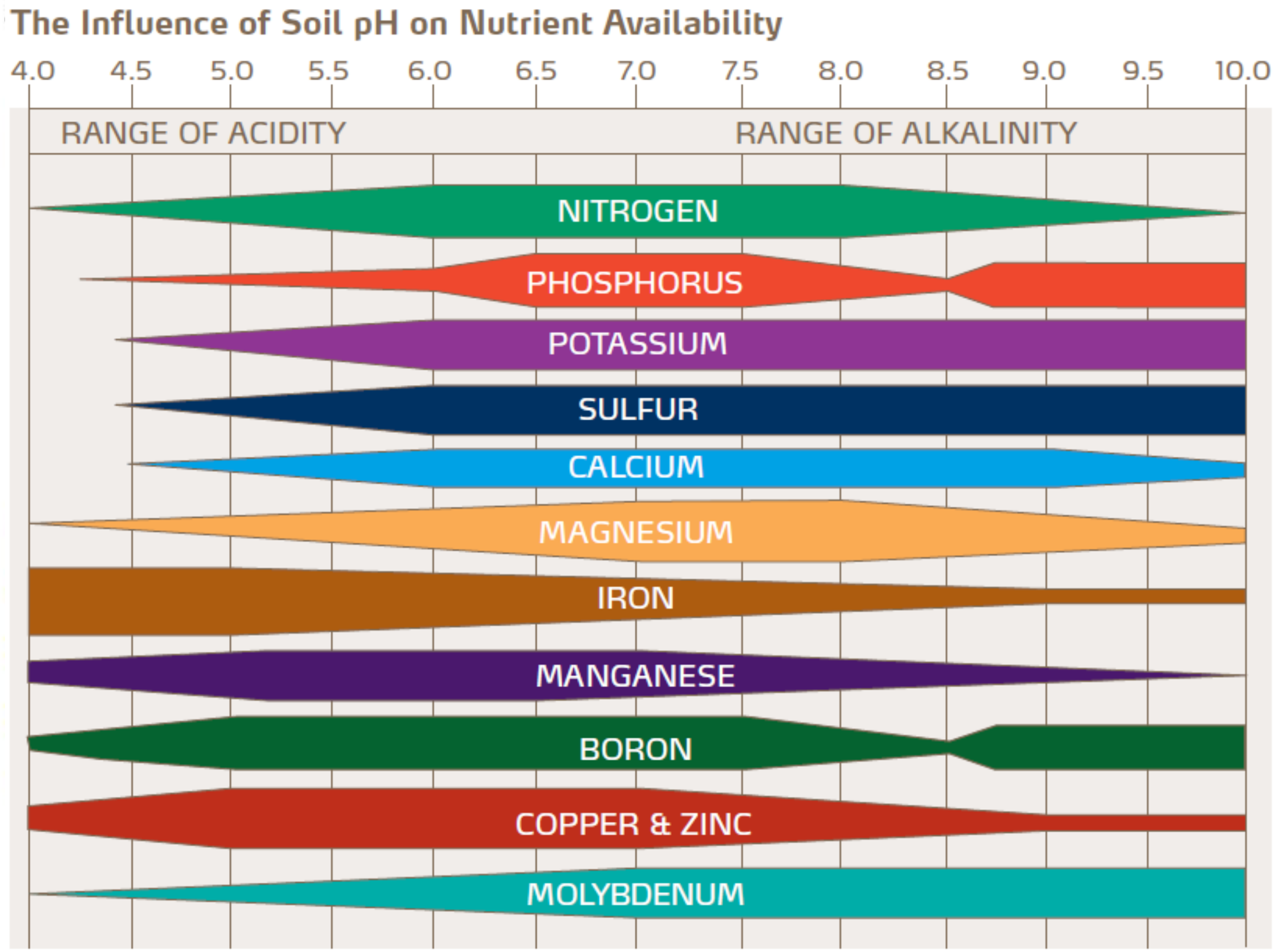
Beneficial elements

- In addition to the essential mineral elements are the **beneficial elements** (functional elements) - elements which promote plant growth in many plant species but are not absolutely necessary for completion of the plant life cycle, or fail to meet *Arnon and Stout's criteria* on other grounds.
- Recognized beneficial elements are: Silicon (Si), Sodium (Na), Selenium (Se), Cobalt (Co)

Plant Nutrient Forms Absorbed

Elements	Abb.	Forms absorbed		
		Positive charge	Negative charge	No charge
Macro-nutrients				
Nitrogen	**N**	NH_4^+ (ammonium)	NO_3^- (nitrate)	Urea
Phosphorus	**P**		$H_2PO_4^-$ and HPO_4^{2} (orthophosphate)	
Potassium	**K**	K^+		
Magnesium	**Mg**	Mg^{+2}		
Calcium	**Ca**	Ca^{+2}		
Sulfur	**S**		SO_4^{-2}(sulfate)	
Micro-nutrients				
Boron	**B**		$H_2BO_3^-$ (borate)	H_3BO_3 (boric acid)
Copper	**Cu**	Cu^{+2}		
Zinc	**Zn**	Zn^{+2}		
Iron	**Fe**	Fe^{+2} (ferrous) and Fe^{+3} (ferric)		
Manganese	Mn	Mn^{+2}		
Molybdenum	Mo		MoO_4^{-2} (molybdate)	

Soil pH and Nutrient Availability



Nutrient Conversion Table

Element Forms						
From	To	Multiply by		From	To	Multiply by
NH_4	$N\text{-}NH_4$	0.777		$N\text{-}NH_4$	NH_4	1.287
NO_3	$N\text{-}NO_3$	0.226		$N\text{-}NO_3$	NO_3	4.426
P_2O_5	P	0.436		P	P_2O_5	2.292
K_2O	K	0.830		K	K2O	1.205
MgO	Mg	0.603		Mg	MgO	1.658
B_2O_3	B	0.310		B	B_2O_3	3.230
SO_4	S	0.334		S	SO_4	2.996
CaO	Ca	0.715		Ca	CaO	1.399

Fertilizer

- A **fertilizer** is any material of natural or synthetic origin (other than liming materials) that is applied to soils or to plant tissues (usually leaves) to supply one or more plant nutrients essential to the growth of plants.
- **Organic fertilizers** are fertilizers derived from organic matter - animal matter, human excreta or vegetable matter (e.g. compost, manure)
- **Inorganic fertilizers** are those made from or containing material that does not come from plants or animals, and therefore exclude carbon-containing materials except ureas.

Fertilizers (IFA)

1. **Form & content**
   - Fertilizers are any solid, liquid or gaseous substances containing one or more plant nutrients.
2. **Application**
   - They are either applied to the soil, directly on the plant (foliage) or added to aqueous solutions (fertigation), in order to maintain soil fertility, improve crop development, improve yield and/or crop quality.
3. **Purpose**
   - The purpose of fertilizers are to supplement the natural supply of soil nutrient, build up soil fertility in order to satisfy the demand of crops with a high yield potential and to compensate for the nutrients taken by harvested products or lost by unavoidable leakages to the environment, in order to maintain good soil conditions for cropping.

Fertilizer Classifications

- **Number of nutrients**
  - single-nutrient or straight fertilizers (whether for macro or micronutrients);
  - multi-nutrient/compound fertilizers, with 2, 3 or more nutrients.
- **Type of combination**
  - Mixed fertilizers or 'bulk-blends' are physical mixtures of two or more single-nutrient or multi-nutrient fertilizers.
  - Compound fertilizers are granulated NPKs, and include fertilizers produced using the processes of wet (steam/water) granulation, dry granulation (compaction), chemical granulation, or drop granulation (prilling).
- **Physical condition**
  - solid (crystalline, powdered, prilled or granular) of various size ranges;
  - liquid (solutions and suspensions);
  - gaseous (liquid under pressure, e.g. ammonia).
- **Nutrient release**
  - quick-acting (water-soluble and immediately available);
  - slow-acting (transformation into soluble form required, e.g. direct application of phosphate rock);
  - slow-release by chemical structure
  - controlled-release by coating;
  - stabilized by inhibitors.

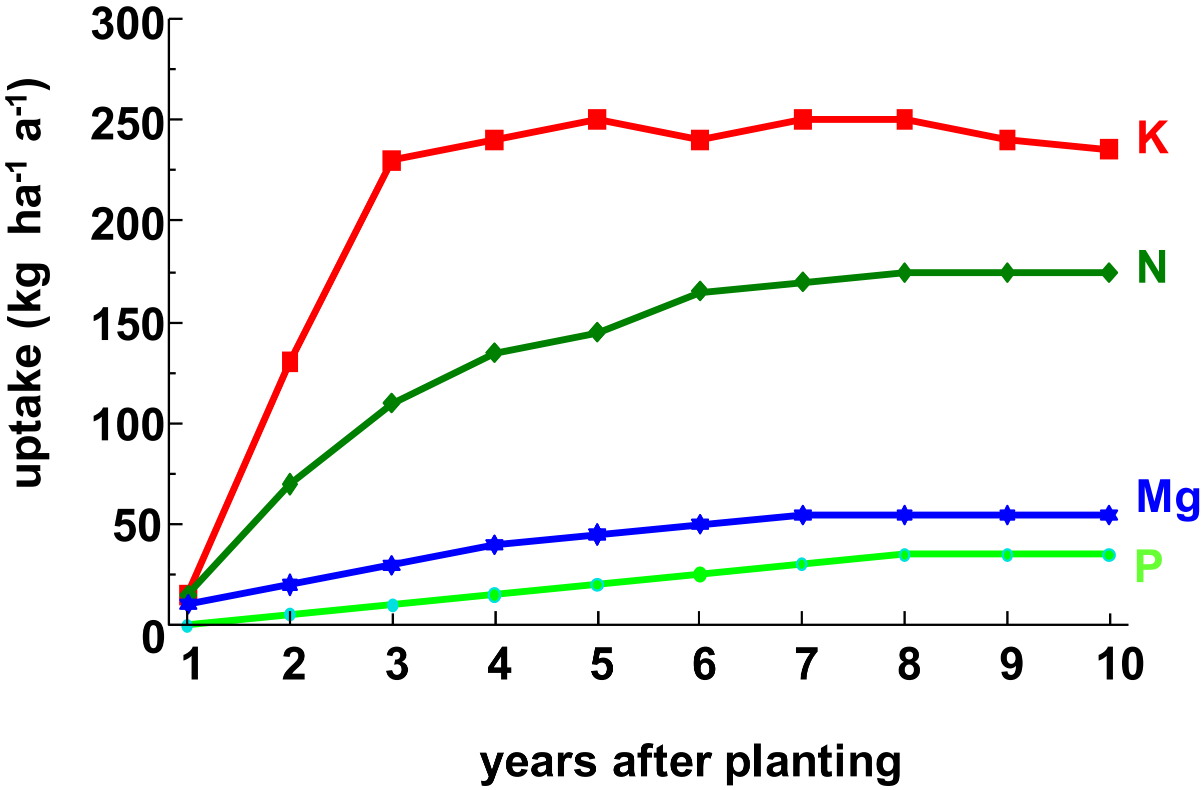
Main nutrients in oil palm supplied as fertilizers

Macronutrients

- **Nitrogen (N)**
- **Phosphorus (P)**
- **Potassium (K)**
- **Magnesium (Mg)**
- ***Sulphur (S)***
- ***Calcium (Ca)***

Micronutrients

- **Boron (B)**
- **Copper (Cu)**
- **Zinc (Zn)**
- **Iron (Fe)**



Nitrogen fertilizers

Common N-fertilizers in Malaysia

N-fertilizer	A.I.	N	P_2O_5	K_2O	MgO	S	B_2O_3
Ammonium sulphate (AS, SOA)	**$(NH_4)_2SO_4$**	**21**	-	-	-	**23**	-
Ammonium chloride (AC)	**NH_4Cl**	**25**	-	-	-	-	-
Ammonium nitrate (AN)	NH_4NO_3	34	-	-	-	-	-
Urea	**$CO(NH_2)_2$**	**46**	-	-	-	-	-
(DAP)	$(NH_4)_2HPO_4$	18	46	-	-	-	-
(MAP)	$NH_4H_2PO_4$	10-11	50-52	-	-	-	-

Nutrients as % of product; represents the normal nutrient contents available commercially.

Nitrogen fertilizers

Soil acidification by N-fertilizers

N-fertilizer	Amount of CaO to compensate the soil acidification induced by 1kg N*
CAN	0.6 kg
Urea, AN	1 kg
DAP, ASN	2 kg
AS	3 kg

** On the basis of 50% utilization.*

Nitrogen fertilizers

Nitrogen uptake

- Plants have ability to take up several chemical forms of nitrogen
- The most common are:
  - Ammonium form (**NH_4^+**)
    - positive charge
  - Nitrate form (**$N0_3^-$**)
    – negative charge
  - Urea (**$CO(NH_2)_2$**)
    – no charge

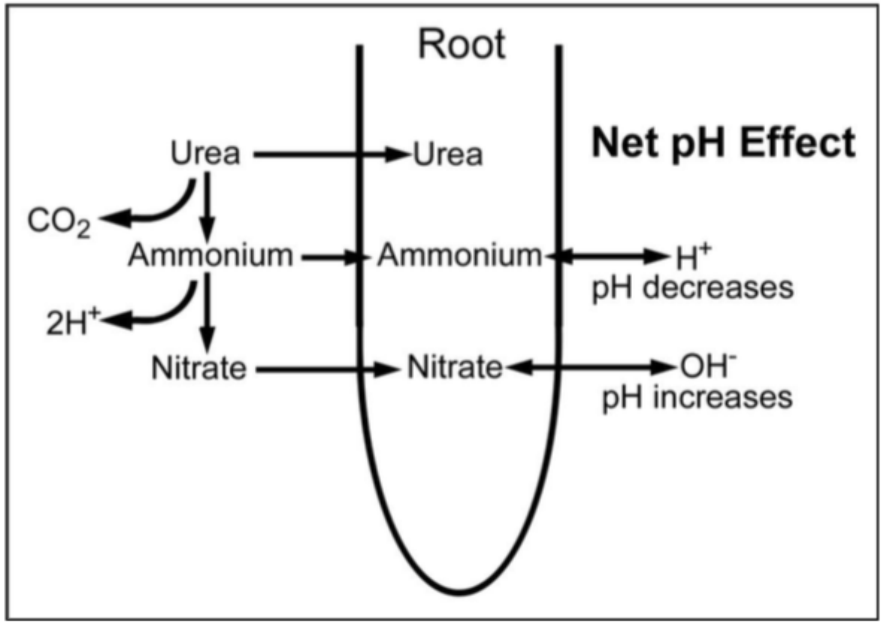


Figure 1. Conversions between nitrogen form and effect of nitrogen uptake on root-zone pH.

Phosphorus fertilizers

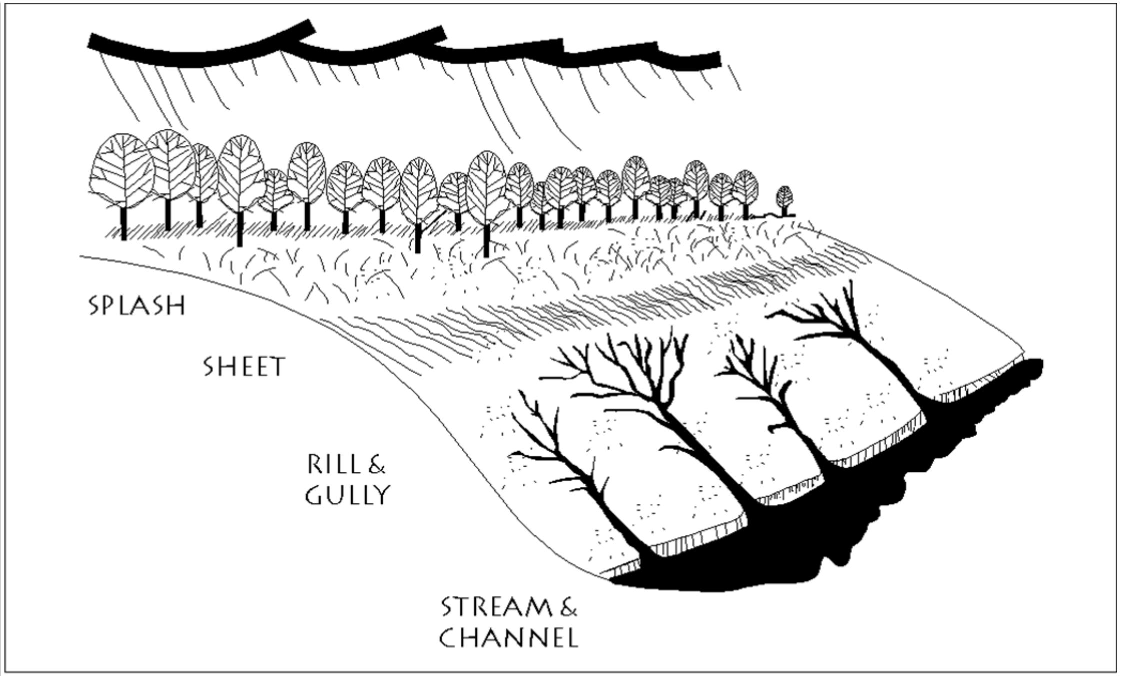
Common P-fertilizers in Malaysia

P-fertilizer	A.I.	N	P_2O_5	S	CaO
Single super phosphate (SSP)	**$Ca(H_2PO_4)_2H_2O$ + $CaSO_42H_2O$**	**-**	16-20	11-12	28-30
Triple super phosphate (TSP)	**$Ca(H_2PO_4)_2.2H_2O$**	**-**	46-48	2	20
Di-ammonium phosphate (DAP)	**$(NH_4)_2HPO_4$**	**18**	**46**	-	
Mono-ammonium phosphate (MAP)	$NH_4H_2PO_4$	10-12	50-52	-	
Ground Rock Phosphate	**$Ca_3(PO_4)_2$**		**28-34***	-	**46-50**
** Citrate soluble P_2O_5 is usually 6-8% of product, or less than 1/3 of total P_2O_5.*					

Nutrients as % of product; represents the normal nutrient contents available commercially.

PHOSPHORUS FERTILIZERS

SOIL SURFACE RUN-OFF LOSSES



Loss of both top-soil and fertilizers that remain undissolved.

The prevalent view that directly applied Rock Phosphates remain available for long periods of time is basically flawed because, as un-dissolved particles on the soil surface, they are quickly lost with surface run-off especially in high rainfall areas.

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Soil losses in high rainfall tropics

Effects of different forms of cover on soil loss and runoff at Kemaman

Water year	Rainfull (mm)	Soil loss (t/ha)		Runoff (mm)	
		T1	T2	T1	T2
1989-1990	2738	26.43	11.65	628	355
1990-1991	2971	90.55	2.99	1088	268
1991-1992	3599	77.21	7.34	1234	471
1992-1993	3829	118.35	16.34	1463	409
Average	3284	78.14	9.58	1088	376
T1	High aerial cover. Larger and more pronounced preferred pathways; contact cover is leaf and twig litter.				
T2	High aerial cover. Smaller and less pronounced preferred pathways; contact cover are living vegetation and litter.				

Ref: Hashim G.M. (2003). Prevention and mitigation of soil erosion. In: *Managing Soil Erosion and Nutrient Depletion* p. 81. Serdang, Malaysia: MARDI

Phosphorus fertilizers

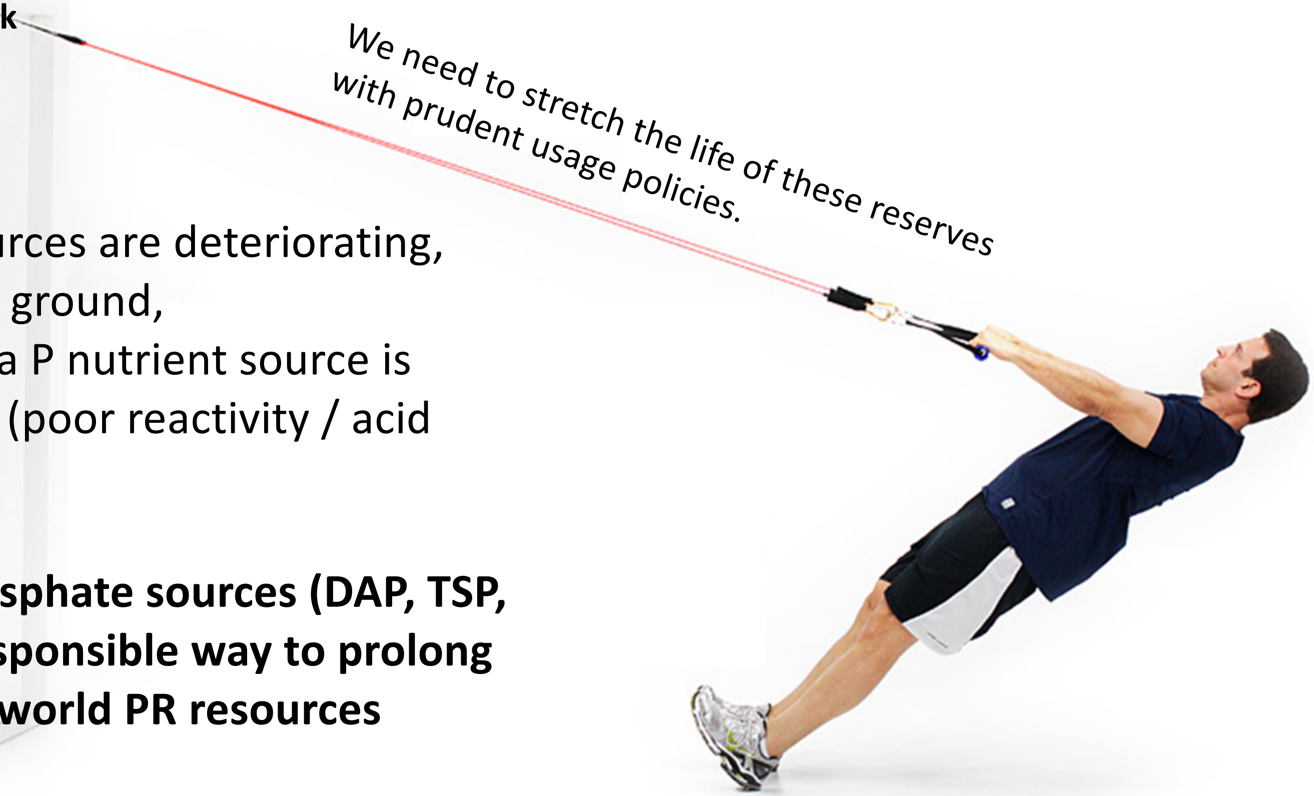
Soluble P vs Rock Phosphate

Trial		P0	P1	P2
1	DSP* – Yield	5.33	5.91 (+10.9%)	6.28 (+17.8%)
	DSP – Leaf P (%)	0.157	0.173 (+10.2%)	0.175 (+11.5%)
2	RP - Yield	8.55	8.97 (+4.9%)	8.72 (+2.0%)
	RP – Leaf P (%)	0.179	0.184 (+2.8%)	0.185 (+3.4%)
3	RP - Yield	8.89	8.97 (+0.9%)	9.44 (+6.2%)
	RP – Leaf P (%)	0.168	0.176 (+4.8%	0.178 (+6.0%)
** Double super phosphate*				
Lo, KK, Goh, K.H., Hardon, J.J. *"Effect of manuring on yield, vegetative growth and leaf nutrient level of the oil palm."* Advances in Oil Palm Cultivation, ISP (1972).				

Phosphorus fertilizers

LIMITED PHOSPHATE ROCK RESERVES

Phosphate rock is a non-renewable nutrient resource. It's usage as a fertilizer nutrient source takes up more than 90% of usage. At current consumption level, known reserves may last only from between 100-300 years.



Phosphate rock:

- Quality of most sources are deteriorating,
- Supplies are poorly ground,
- Directly applied as a P nutrient source is poorly dependable (poor reactivity / acid solubility)

Use of acidulated phosphate sources (DAP, TSP, MAP, SSP, NPs) is a responsible way to prolong availability of limited world PR resources

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Potassium & Magnesium fertilizers

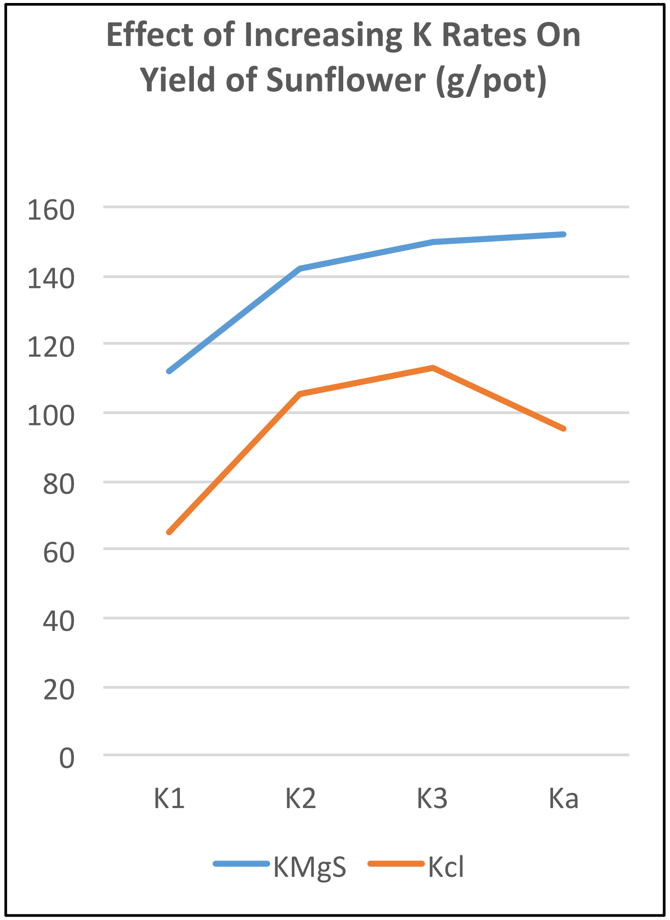
K & Mg-fertilizer	A.I.	N	P_2O_5	K_2O	MgO	S	B_2O_3
Potassium chloride (MOP)	**KCl**	**-**	-	**60**	-	-	-
Potassium sulphate (SOP)	K_2SO_4	**-**	-	50	-	18	-
Potassoium nitrate	KNO_3	13	-	44	-	-	-
Potassium magnesium sulphate	$K_2 SO_4 .2MgSO_4$	-	**-**	18	22	22	
Korn-Kali+B	**$KCl + MgSO_4 + H_3BO_3$**	-	**-**	**40**	**6**	**4**	**0.8**
Kieserite (mineral)	**$MgSO_4.H_2O$**	-	-	**2**	**26**	**21**	-
Magnesium sulphate (precipitate)	$MgSO_4.xH_2O$	-	**-**	-	25	20	-
Magnesium sulphate (synthetic)	**$MgSO_4.xH_2O$**	**-**	**-**	**-**	**23-25**	**18-20**	**-**

Nutrients as % of product; represents the normal nutrient contents available commercially.

K & Mg – mutual antagonism

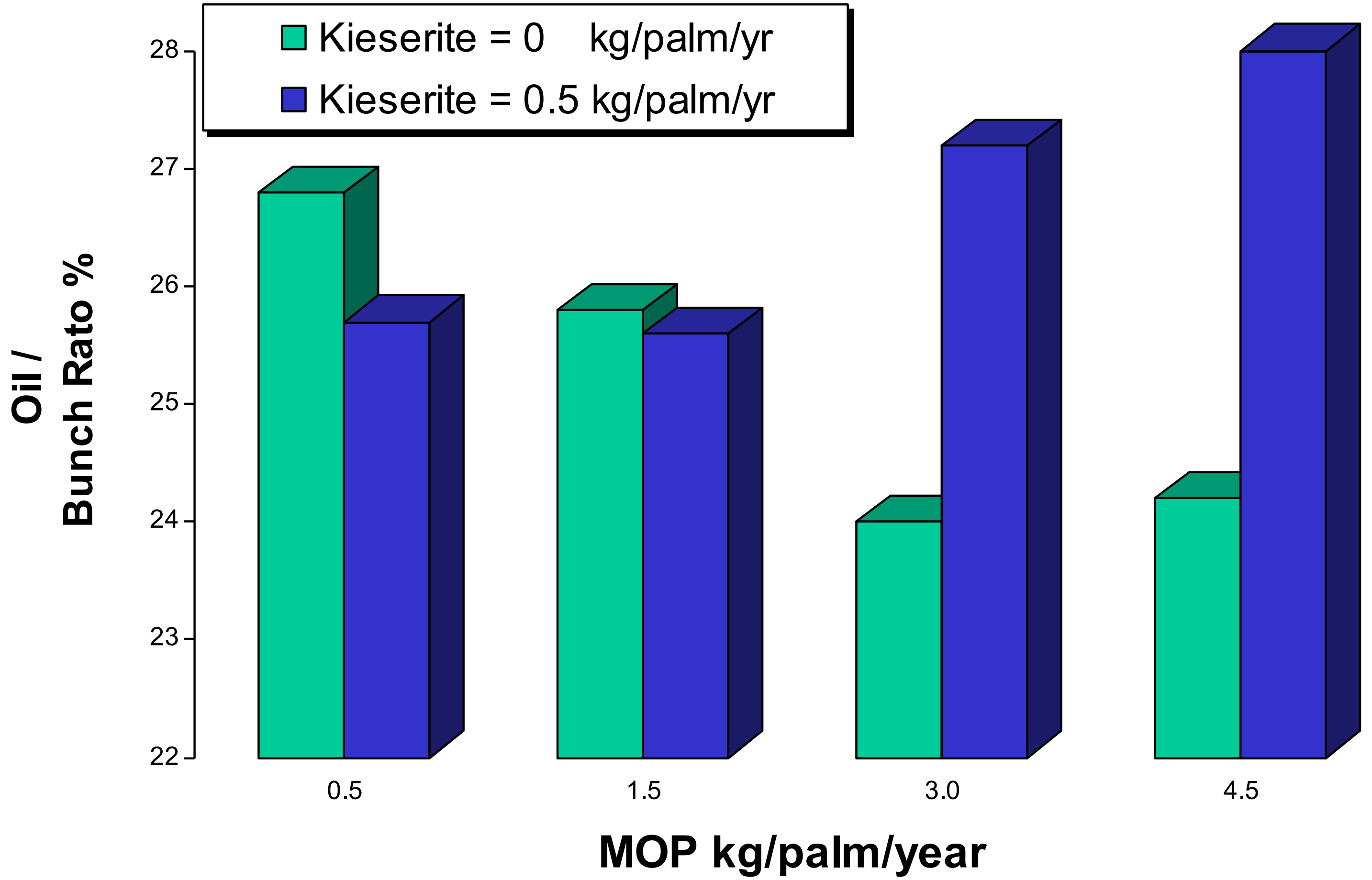
- Plants tend to keep the sum of the cations K, Na, Ca, and Mg fairly constant.
- If any one is present in the soil to excess it will tend to be absorbed at the expense of the others e.g. MOP applied in a large single increase will inhibit Mg uptake and cause Mg deficiency symptoms, even though soil Mg levels may be adequate. The reverse is also possible.

“Why apply magnesium with potash?“. Plant Nutrition. Phosphorus & Potassium No 161 (May-June,1989)



Potassium & Magnesium fertilizers

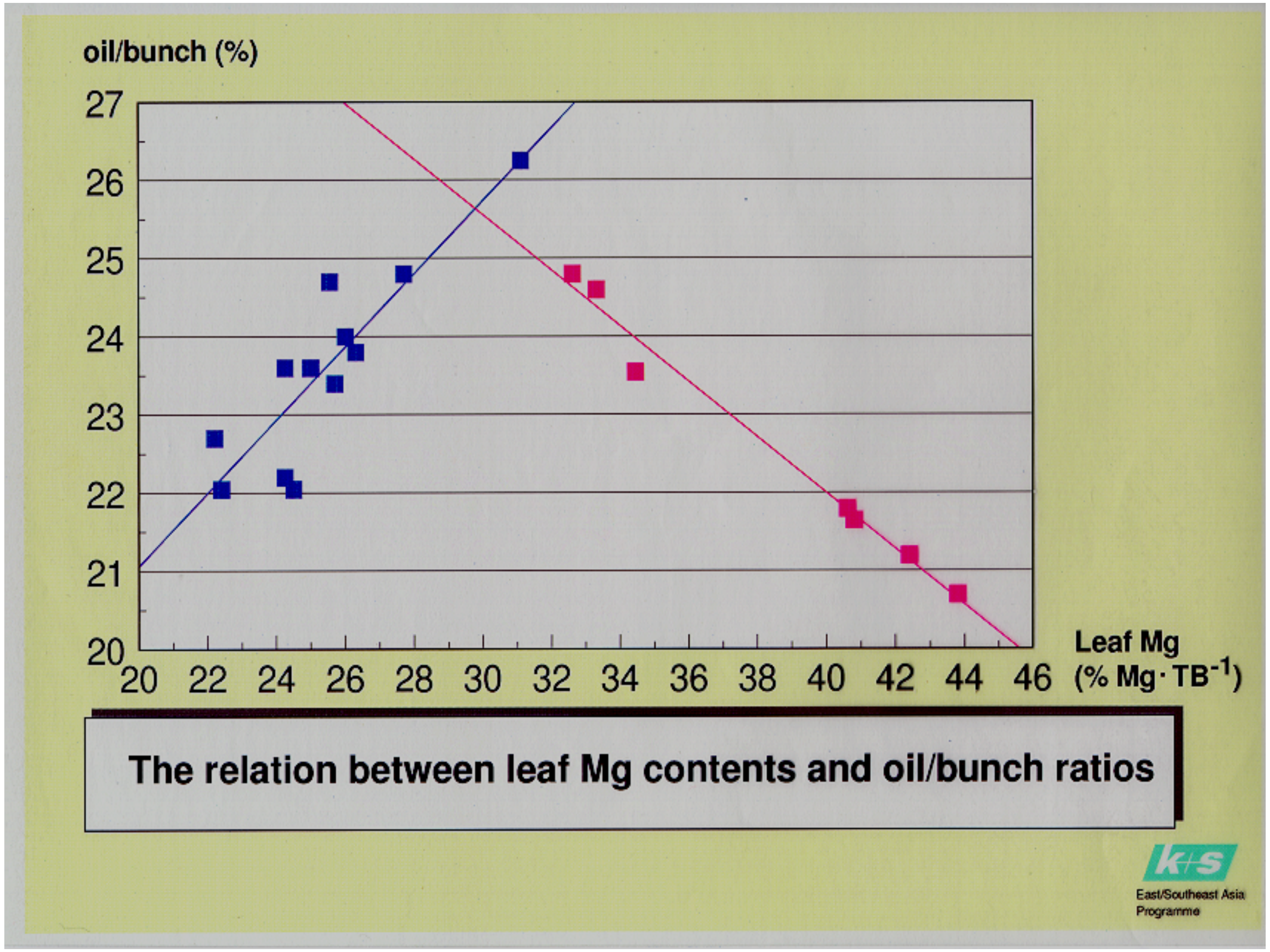
Effect of Potassium and Magnesium on oil/bunch ratio % of Oil Palms



Source: Ochs & Orlagnier, 1977 (IRHO)

Potassium & Magnesium fertilizers

Effect of Mg on oil/bunch % of Oil Palm



Source: "The Effects of Fertilizers on the Yield & Composition of Lipids in Some Tropical Crops" by R.C.Ochs & M.Ollagnier (IRHO)

The significance of Magnesium supply on FFB and oil yield are well documented: oil yield

Treatment	Year 5	Years 1-5 combined	Oil to bunch ratio
	($t\ ha^{-1}$)	($t\ ha^{-1}$)	
N+P+SOP	4.35 b	6.00	27.90
N+P+SOP+1.5 Mg	5.92 a	6.54	28.49
N+P+SOP+3.0 Mg			29.27

- Magnesium (Kieserite) significantly increased FFB yield, oil content (O/B) and oil yield
- An extra 0.57 $t\ ha^{-1}\ year^{-1}$ oil was obtained by application of 1.5 kg Mg $palm^{-1}\ year^{-1}$ as ESTA Kieserite

Source: Dolmat, MPOB, 2005

Boron fertilizers

B-fertilizer	Solubility	A.I.	B	B_2O_3	CaO
Sodium borate pentahydrate	**Water soluble**	**$Na_2B_4O_7.5H_2O$**	**15**	**48**	-
Sodium borate decahydrate (Borax)	Water soluble	$Na_2B_4O_7.10H_2O$	11	36	-
Ulexite (Boron atrocalcite)	Mainly citric acid soluble	$CaNaB_6O_9.8H_2O$ $NaCaB_5O_6(OH)_6.5H_2O$	13	43	14
Calcined ulexite	**Slightly water soluble (10%), mainly citric acid soluble**	**$Na_2O.2CaO.5B_2O_3.nH_2O$**	**14**	**46**	**16**
Colemanite (Calcium borate)	Mainly citric acid soluble	$Ca_2B_6O_{11}.5H_2O$ or $CaB_3O_4(OH)_3 \cdot H_2O$	15.8	51	27

Nutrients as % of product; represents the normal nutrient contents available commercially.

Boron fertilizers

Phloem Mobility and Re-Translocation of Nutrients

Phloem mobile	Not phloem mobile	
Remobilisation possible	No remobilisation	
High	Low	
K	(Cu)	Ca
Mg	Zn	B (most crops)
N (as N_{org})	Fe	Mo
P	S	
B (in some crops e.g. *Rosaceae*)	**Deficiency symptoms at youngest leaves**	

Boron fetilizers

BORON IN OIL PALM

1. B is phloem-immobile in oil palm, as in most plants, and requires constant availability from the soil
2. Frond-17 level is not a good indicator of B-status; sampling of younger fronds is not practical
3. B-deficiency in oil palm causes reduced leaf area, fruit parthenocarpy, and reduced yields
4. Sodium borate which is commonly used is very soluble and easily leached
5. Small amount of 100-200g per palm is difficult to apply and supervise
6. Possible solutions:
   - Use less soluble B-sources e.g. calcined ulexite
   - Apply in multiple applications via B-containing fertilizers

Boron fetilizers

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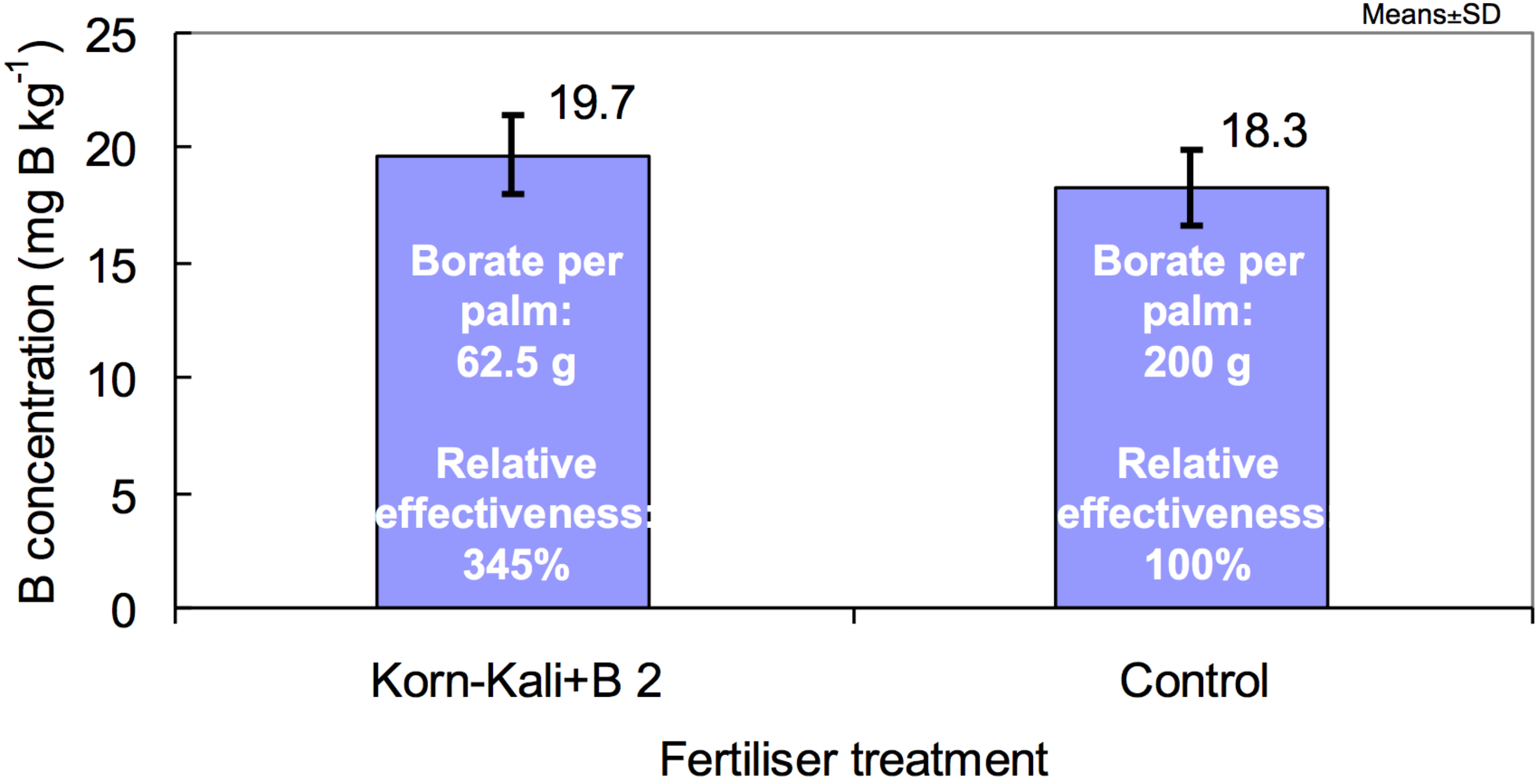
Comparative efficiency of boron (B) application: straights vs. macronutrient fertiliser as carrier



More efficient B application with Korn-Kali+B

USING A MACRO-NUTRIENT TO CARRY MICRONUTRIENTS

KieserBor *23-5*

Special Features

1. Kieserite acts as carrier for small quantity of B
2. Components: ESTA Kieserite for Mg and Anchor-Bor (slow-release form) for B
3. 1kg contains 900g Kieserite and 100g Borate
4. Offers 3 advantages:
   - Easy application and supervision
   - Even spread of B
   - Slow-release B for oil palm in which B is phloem immobile (there is a need for constant availability in the soil)

Fertilizers containing sulphur

K & Mg-fertilizer	A.I.	N	P_2O_5	K_2O	MgO	S	B_2O_3
Ammonium sulphate (AS)	**$(NH_4)_2SO_4$**	**21**	-	-	-	**23**	-
Potassium sulphate (SOP)	K_2SO_4	-	-	50	-	18	-
Single super phosphate	$Ca(H_2PO_4)_2H_2O$ + $CaSO_42H_2O$	-	16-20			11-12	
Triple super phosphate	$Ca(H_2PO_4)_2.2H_2O$	-	46-48			2	
Potassium magnesium sulphate	$K_2 SO_4 .2MgSO_4$	-	-	18	22	22	
Korn-Kali+B	**$KCl + MgSO_4 + H_3BO_3$**	-	-	**40**	**6**	**4**	**0.8**
Kieserite (mineral)	**$MgSO_4.H_2O$**	-	-	**2**	**26**	**21**	-
Magnesium sulphate (precipitate)	$MgSO_4.xH_2O$	-	-	-	25	20	-
Magnesium sulphate (synthetic)	**$MgSO_4.xH_2O$**	**-**	**-**	**-**	**23-25**	**18-20**	**-**

Nutrients as % of product; represents the normal nutrient contents available commercially.

Sulphur containing fertilizers

K & Mg-fertilizer	A.I.	N	P_2O_5	K_2O	MgO	S	B_2O_3
Ammonium sulphate (AS)	**$(NH_4)_2SO_4$**	**21**	-	-	-	**23**	-
Potassium sulphate (SOP)	K_2SO_4	-	-	50	-	18	-
Single super phosphate	$Ca(H_2PO_4)_2H_2O$ + $CaSO_42H_2O$	-	16-20			11-12	
Triple super phosphate	$Ca(H_2PO_4)_2.2H_2O$	-	46-48			2	
Potassium magnesium sulphate	$K_2 SO_4 .2MgSO_4$	-	-	18	22	22	
Korn-Kali+B	**$KCl + MgSO_4 + H_3BO_3$**	-	-	**40**	**6**	**4**	**0.8**
Kieserite (mineral)	**$MgSO_4.H_2O$**	-	-	**2**	**26**	**21**	-
Magnesium sulphate (precipitate)	$MgSO_4.xH_2O$	-	-	-	25	20	-
Magnesium sulphate (synthetic)	**$MgSO_4.xH_2O$**	**-**	**-**	**-**	**23-25**	**18-20**	**-**

Nutrients as % of product; represents the normal nutrient contents available commercially.

K+S KALI GmbH

Function of Sulphur (S) in plant growth and metabolism

- S-containing amino acids
  → protein formation (all enzymes are proteins!)
  → N use efficiency (N cannot be used without S!)
- Enzyme activity (many co-factors of enzymes contain S)
  → Oil synthesis!
- Sulphur deficiency symptoms in oil palm are rarely reported, … but leaf analysis indicates that the S status is declining!


Source: IPNI, used by permission

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Symptoms of nutrient deficiencies are related to their function: Sulphur (S)

Lack of sulphur impairs synthesis of amino acids and proteins →

- **Symptoms similar to N deficiency**

S is not mobilised in older leaves →

- **Symptoms more pronounced on younger leaves**

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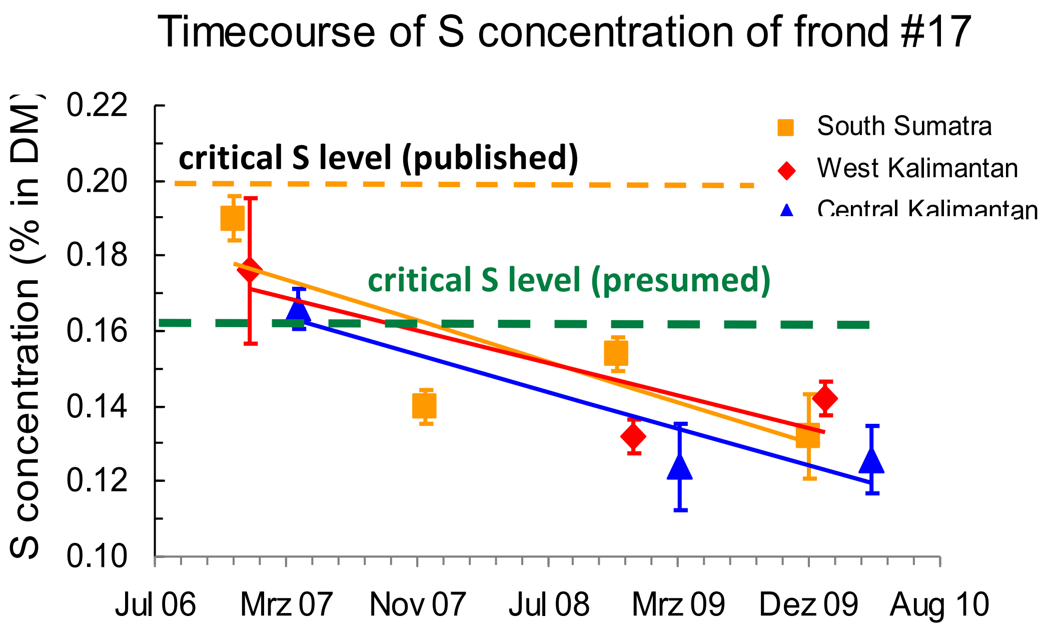
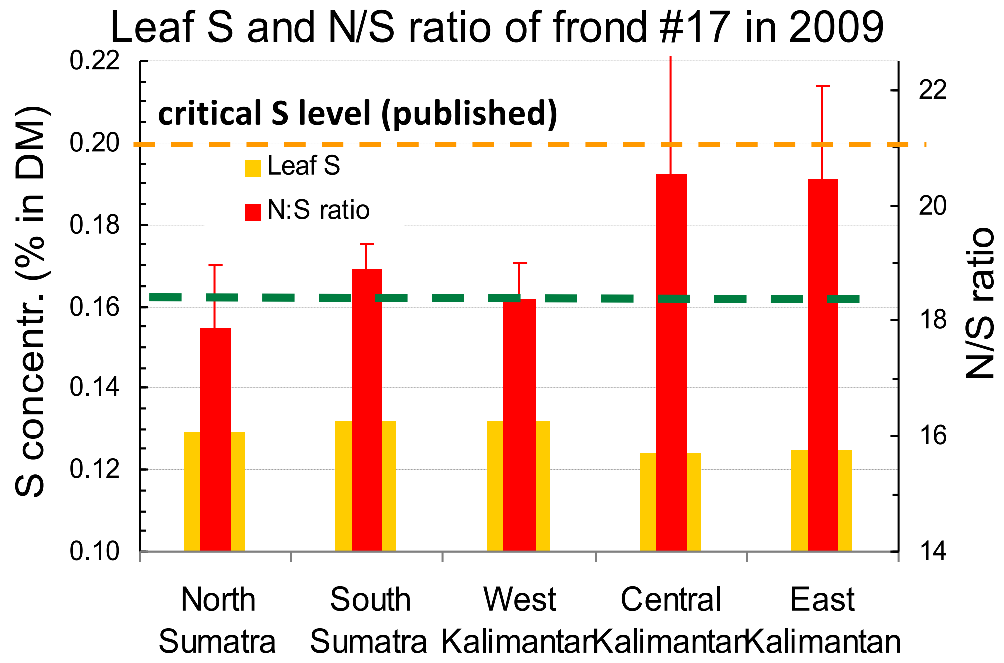
The Sulphur (S) status of oil palm: Some data from the IPNI BMP project (SE Asia programme)





The S status of oil palm in Indonesian is declining! This trend is particularly strong in Kalimantan

Source: Gerendás, Donough & Oberthür, MSSS SOILS conference, 2011

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SOILS conference
Malaysian Soil Science Conference (MSSS)

Kota Kinabalu, Sabah
18-21 April, 2011

Low Sulphur Status of Oil Palm in Indonesia

J. Gerendás[1], C. R. Donough[2], T. Oberthur[3]

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Background

The macronutrient sulphur (S) is a component of S-containing amino acids, and therefore essential for protein formation. Sulphur is also essentially required for oil synthesis. The S status of oil palm (OP) has not received much attention as it was assumed that the S requirement is met by natural deposition and application of S-containing fertilisers. However, in oil palm plantations in Kalimantan S-free fertilisers (urea, KCl, dolomite, rock phosphate) gained popularity during the last decades. There is a potential risk of S supply being insufficient, but data that allow assessing the S status were not available.

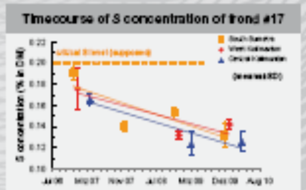
Approach

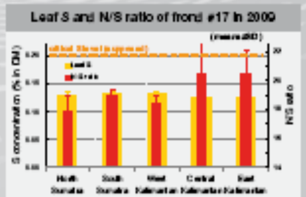
In the course of a BMP (Best Management Practise) project initiated by IPNI SEA in July 2006 comprising 30 commercial-size blocks (total area 1,080 ha) in six locations in Sumatra and Kalimantan the leaf nutrient status was regularly assessed by analysis of frond #17.

Results & Discussion

A continuous decline in the S status is apparent in both Sumatra and Kalimantan. Only the data of the reference blocks (estate standard management) are shown here, but the BMP blocks were not significantly different. In tendency, lower levels were reported for Kalimantan as compared to Sumatra.

At all sites the S status is far below the published critical concentration of 0.2% S (Fairhurst et al., 2005), but the N/S ratio often serves as a more reliable indicator. Ratios above 16 are usually considered inadequate, and in this study no ratio was below 18. It has been suggested that the critical S level may be around 0.16% (Fairhurst and Härdter, 2003), which would be equivalent to a N/S ratio of 16/1, given an adequate N concentration of 2.5%. The S status of oil palm reported here is even below this refined critical S level of 0.16%.





Conclusions

The S status of oil palm in Indonesia is to be considered marginal, even when considering a putatively lower critical S level of 0.16%. Apparently, a yield response to S has not been documented yet. Therefore, experiments are currently being initiated to (1) to re-evaluate the critical S concentration and (2) to assess the yield response to S supply at commercial block scale.

Even though experimental evidence is still missing, planters should consider improving the S supply by applying S-containing fertilisers (mostly sulphates of ammonium, K and Mg, acidulated rock phosphates, and S-amended NPKs). Among these kieserite ($MgSO_4 \cdot H_2O$) seems promising due to its suitable composition (16% Mg; 21% S) as compared to plant nutrient demand.

Acknowledgements

All data presented were collected by staff of collaborating plantations. We thank the Management of these companies for permission to use the information shown, and the Senior Management of our collaborating plantations, and the Management teams in collaborating estates for their interest and support.

References:

Fairhurst and Härdter (2003) Oil Palm – Management for large and sustainable yields. ISBN 981-04-8485-2

Fairhurst et al. (2005) Oil Palm – Nutrient disorders and nutrient management. ISBN 981-05-2452-9

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International Plant Nutrition Institute

MULTI-NUTRIENT FERTILIZERS

1. Mixtures or Blends
    - Dry powder blends
    - Granular bulk blends
2. Compound fertilizers
    - Wet granulation compound fertilizer
    - Dry granulation compound fertilizer
    - Tower granulation compound fertilizer
3. Complex fertilizers
    - Pipe-cross reactors
    - Nitrophosphate process

Multi-nutrient fertilizers

MIXTURES or BLENDS

1. Dry powder blends or mixtures (of a combination of 2-5 straight components of different granulometry)
   - Segregation problems (inaccurate nutrient inputs)
   - Caking problems (e.g. NK mixtures)
   - Quality problems (use of unapproved components e.g. GML or magnesite or SMS instead of Kieserite; poor quality RP, etc)
2. Granular bulk blends (of a combination of 2-5 granular components of similar granulometry)

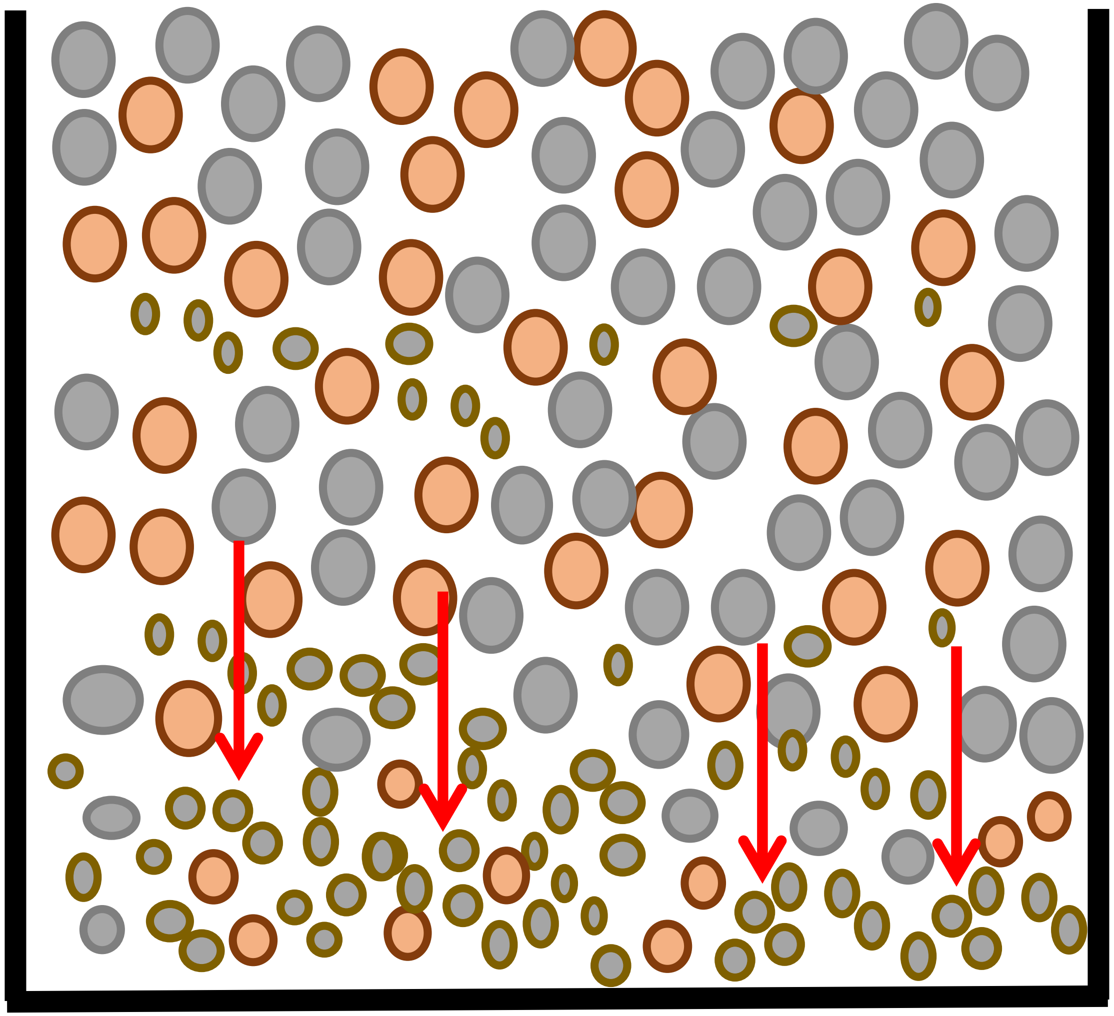
Powder blends

COMPONENTS WITH DIFFERENT GRANULOMETRY

SEGREGATION PROBLEMS

Smaller particles e,g tend to drop to the bottom of the bag or pile.

Common with dry powder blends.



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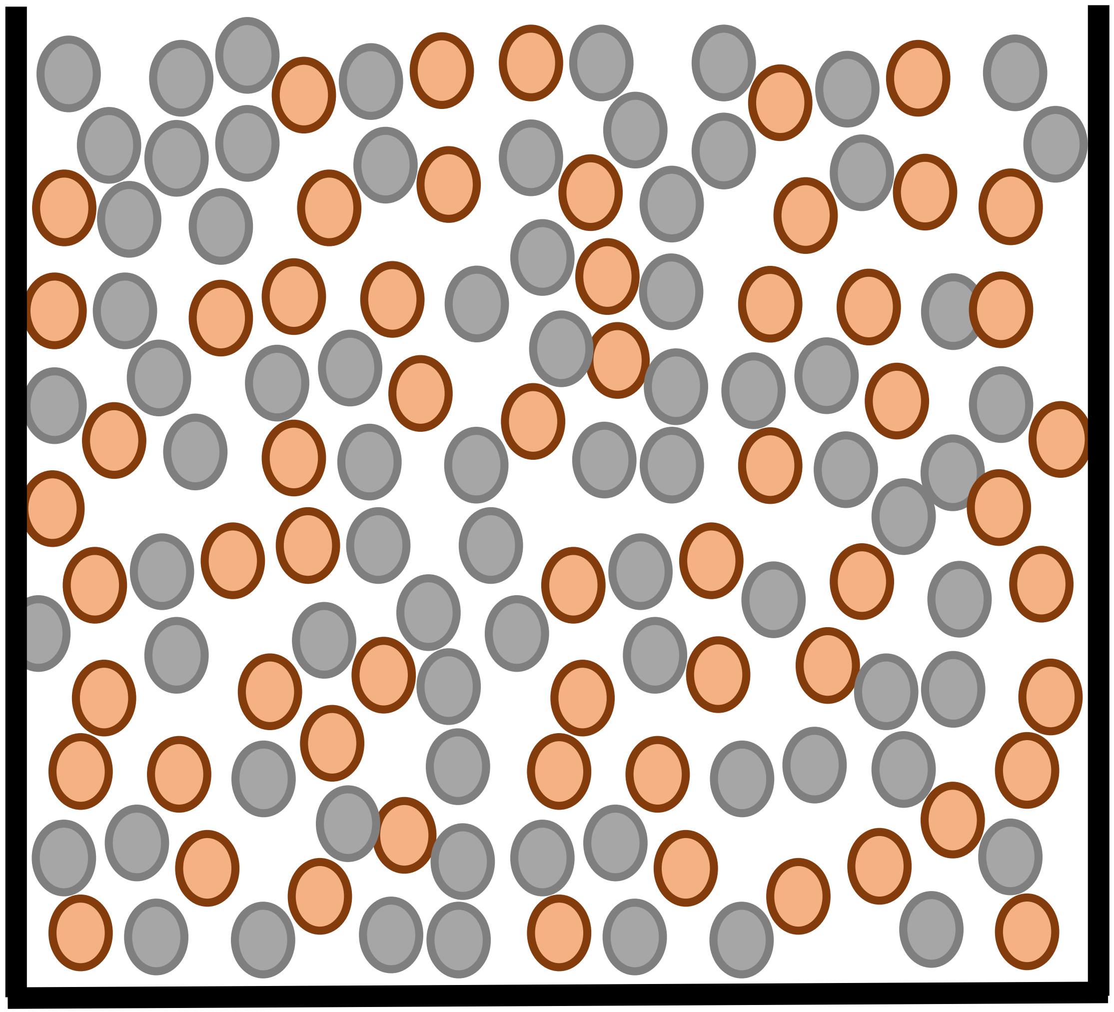
Granular bulk blends

COMPONENTS WITH SIMILAR GRANULOMETRY

MINIMIZED SEGREGATION PROBLEMS

Granules of similar size are less prone to segregation.



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Blends - Chemical Compatibility Chart

Possibilities of mixing fertilizers

(limited compatibility is mainly due to hygroscopicity)

	Ammonium sulphate	Ammonium sulphate nitrate	Amm. nitrate + Ca-carbonate	Urea	Calcium cyanamide	Superphosph., Triplephosph.	Diammonium phosphate	Basig slag	Rock phosphate	K-chloride (MOP)	K-sulphate, K-Mg-sulphate	Calcium carbonate
Ca-nitrate	☒	☒	☒	■	☒	■	☒	☒	☒	☒	☒	☒
Ammonium sulphate	–	☐	■	☒	■	☐	☐	■	☐	☐	☐	■
Ammonium sulphate nitrate	–	–	☐	■	■	☐	☐	■	☒	☒	☐	■
Amm. nitrate + Ca-carbonate	–	–	–	■	■	☒	☐	■	☐	☒	☒	■
Urea	–	–	–	–	■	■	☐	☐	☐	☒	☐	☒
Calcium cyanamide	–	–	–	–	–	■	■	☐	☐	☒	☐	☐
Superphosph., Triplephosph.	–	–	–	–	–	–	☒	■	☐	☐	☐	■
Diammonium phosphate	–	–	–	–	–	–	–	■	☐	☐	☐	■
Basig slag	–	–	–	–	–	–	–	–	☐	☐	☐	☐
Rock phosphate	–	–	–	–	–	–	–	–	–	☐	☐	☐
K-chloride	–	–	–	–	–	–	–	–	–	–	☐	☐
K-sulphate, K-Mg-sulphate	–	–	–	–	–	–	–	–	–	–	–	☐
Calcium carbonate	–	–	–	–	–	–	–	–	–	–	–	–

☐ compatible

☒ limited compatibility

■ not to be mixed

COMPOUND FERTILZERS

Various processes of granulation

1. Wet granulation (liquid phase using steam/water)

a. Granules formed by agglomeration
b. About 75% of the raw materials are fed as "dry" solids
c. Granules formed by interlocking and cementing
d. Granules are soft (1.5-4.0 kg/granule crushing strength)

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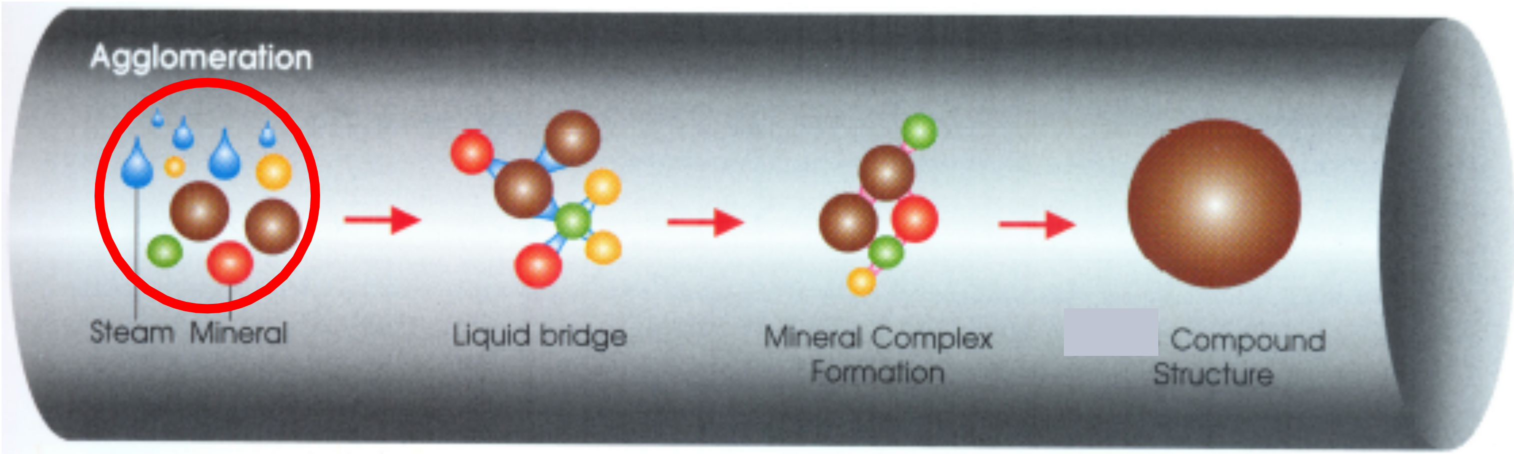
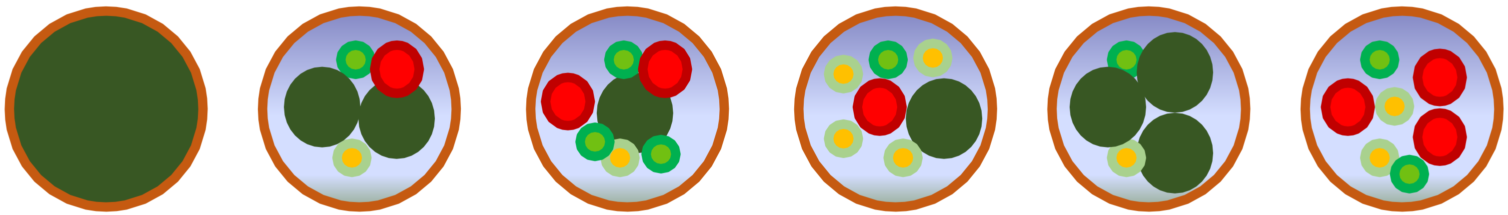
WET-BLEND GRANULATION PROCESS



GRANULATOR

At the wet phase stage - agglomeration of uneven proportions of various components tend to occur - resulting in inconsistent nutrient ratio.



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BEHN MEYER AgriCare

NUTRIENT VARIATIONS
(TOTAL 22 WET GRANULATION SAMPLES)

Sample #	N	P2O5		K2O	MgO		B2O3	TOTAL	K2O/N
		Total	WS	K20	Total	HWS			Ratio
JB 1	-2.5%	19%		-5%	32%	-48%	-73%	-5.3%	0%
LDU 1	-15.0%	-8%		-8%	-10%	-93%	-78%	-18.1%	10%
LDU 2	1.7%	-19%		-4%	-13%	-89%	-77%	-13.1%	-5%
LDU 3	-3.1%	-11%		-2%	15%	-92%	-82%	-13.5%	0%
LDU 4	-6.9%	-23%		135%	-57%	-84%		0.8%	150%
LDU 5	-6.7%	-65%		89%	30%	-62%		12.6%	105%
LDU 6	17.7%	170%	-100%	-77%	69%	-81%		-29.8%	-80%
SDK 1	6.7%	153%		-25%	-61%	-92%		4.3%	-30%
SDK 2	-10.0%	4%		4%	26%	-80%	-41%	-4.8%	15%
SDK 3	3.3%	27%		-57%	138%	-79%	-40%	-18.3%	-60%
SDK 4	-27.3%	-23%		168%	-42%	-73%		-1.0%	270%
SDK 5	-67.4%	-44%		4%	301%	-67%	-92%	-34.2%	220%
SDK 6	-18.9%	-56%		40%				-10.8%	75%
SDK 7	-5.0%	-2%		0%				-3.1%	5%
SJ 1	-7.9%	-9%		3%	4%	-24%		-6.8%	10%
SJ 2	7.5%	-2%	-94%	18%	26%	-70%	-32%	4.5%	10%
SJ 3	2.5%	8%		-7%	17%	-29%	-57%	-5.0%	-10%
SJ 4	-40.3%	-14%		-8%	-50%	-87%	-83%	-25.7%	55%
SJ 5	0.7%	6%		-2%	36%	-63%	-26%	-3.9%	-5%
TWU 1	-19.1%	9%		-4%	10%	-84%	-24%	-11.3%	20%
TWU 2	-25.2%	15%		22%	13%	-78%		1.0%	65%
TWU 3	-9.2%	5%		6%	14%	-82%	-36%	-3.2%	15%

Argus FMB Asian Technical Fertilizer 2014

BEHN MEYER AgriCare

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COMPOUND FERTILZERS

Various processes of granulation

1. Wet granulation (liquid phase using steam/water)

2. Dry granulation (Compaction)

a. Components are dosed and blended
b. Compaction by roller press
c. Granulation by crushers and sieving
d. Granules are hard (>4 kg/granule crushing strength)
e. No wetting and drying
f. More homogenous product

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DRY GRANULATION BY COMPACTION

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BMA LAHAD DATU PLANT

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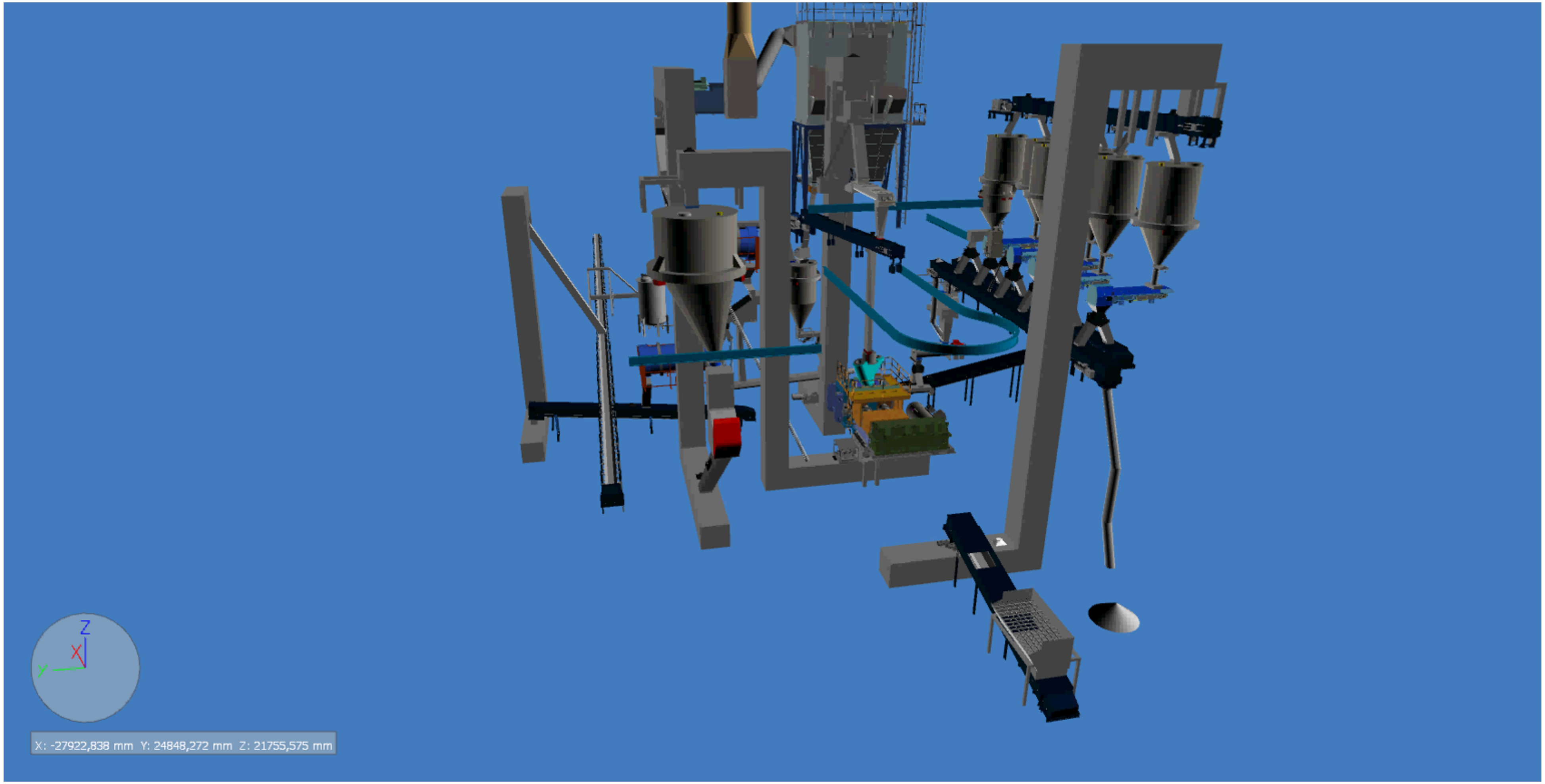
THE HEART OF THE EQUIPMENT



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BEHN MEYER AgriCare

THE FINAL PRODUCTS

» Steam Granulation

» Compaction Granulation

» Bulk Blending

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COMPLEX FERTILZERS

1. **Chemical reaction involved**
   a. cross-pipe reactors (ammonia with acids and other nutrients)
   b. nitrophosphate process (reacting phosphate rock with nitric acid and then adding other nutrients sources)
2. **Granulation by**
   a. Agglomeration – high % of dry materials, or
   b. Accretion ("onion ring" layering) low % of dry material
   c. Prilling (drop formation)
      - Usually some form of chemical reaction is used to form a concentrated solution
      - This is sprayed as droplets which go through a repetition of solidifying and rewetting until it becomes a granule of a desired size and weight which causes it to drop
      - Smaller granules (1.3-3.0mm) are usually produced compared to other methods

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STABILIZED FERTILZERS

These are fertilizer to which a N-stabilizer has been added in order to extend the time the N-component remains in the soil in the urea-N or ammoniacal forms.

1. **Nitrification inhibitors**
   - Inhibits the biological oxidation of ammoniacal-N to nitrate-N
   - Net effects are less leaching losses of nitrate-N, higher uptake by plants of ammoniacal-N
   - E.g. DCD, DMPP
   - Commercial fertilizers - ENTEC
2. **Urease inhibitors**
   - Inhibitsthe hydrolysis of urea by the urease enzyme
   - Net effect of less volatilization losses, increased N-uptake by the plants
   - E.g. NBPT, 2-NPT
   - Commercial fertilizers – Agrotain, UTEC

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SLOW-RELEASE FERTILZERS

These are fertilizer which contain certain nutrient or nutrients that are released slowly into the soil due its complex chemical structure.

1. The nutrient is usually N
2. Examples are urea formaldehyde (UF), crotonylidene diurea (CDU) or isobutyledene-diurea (IBDU)
3. Rate of release is slowed down, and depends on many factors such as
   - the soil microorganism,
   - moisture content, and
   - soil temperature

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CONTROLLED RELEASE FERTILZERS

These are fertilizer in the granular form containing water-soluble nutrients, the release of which in the soil is controlled by a protective, water-insoluble coating applied to it.

1. Duration of release is principally controlled by
   - The soil temperature
   - Choice of coating material
   - Thickness of the coating material
2. Nutrient release is achieved by build up of osmotic pressure within the encapsulated granule
3. Useful in certain situations:
   - Poor manpower supply
   - Fertilizer of "supply" palms
   - Poor accessibility areas
   - Nurseries that are sprinkle irrigated

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MAKING CHOICES

1. COST
   - Straights < Mixtures < Granular blends < Compounds
2. QUALITY
   - Straights > Mixtures < Granular blends =< Compounds (?)
3. PROBLEMS
   - Straights > Mixtures > Granular blends => Compounds (?)

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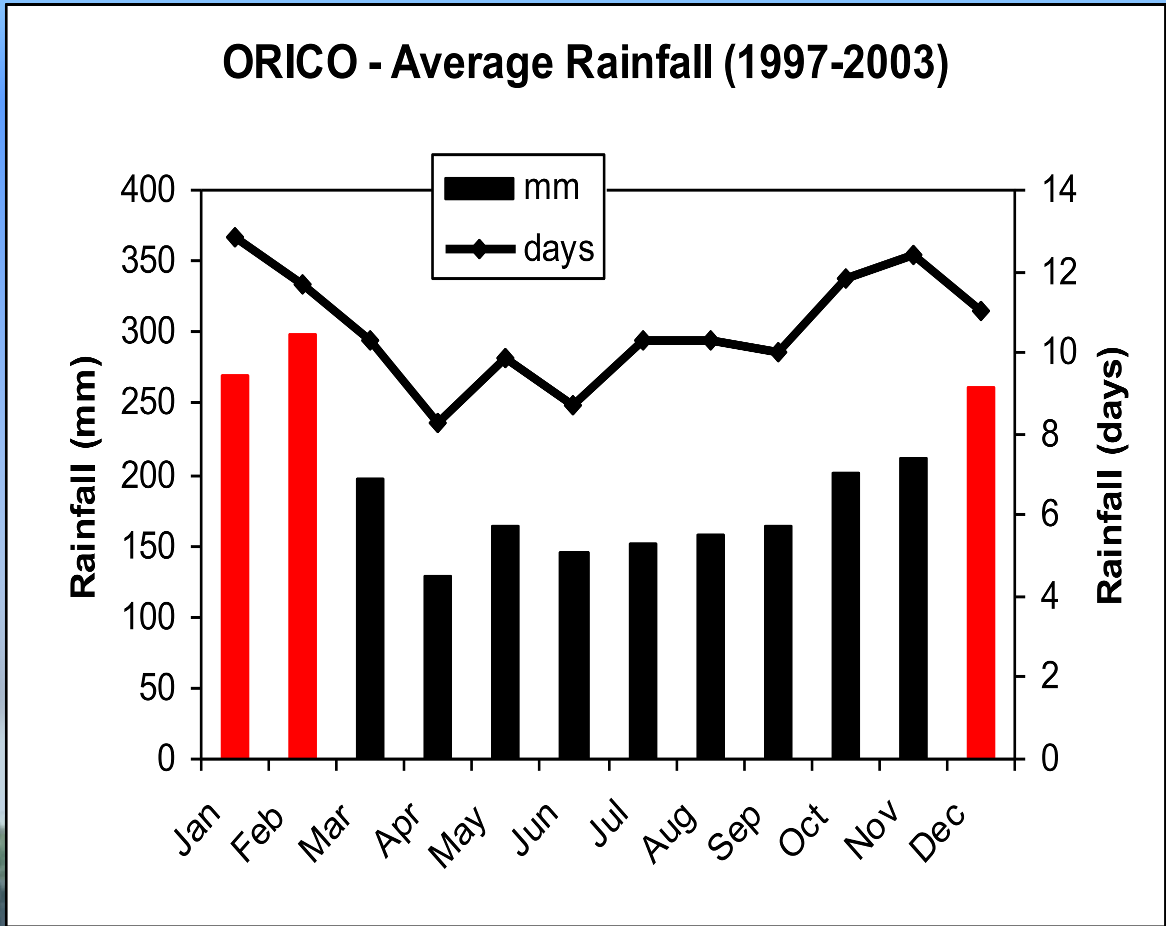
Using straight fertilizers

If a program that is based on straight fertilizers involving up to 7-9 rounds (2-3 rounds N, 2-3 rounds K, 1 round P, 1 round Mg, 1 round B):

- Plantations have great difficulty to complete program within the year (resulting in under fertilization)
- Imbalance of nutrients (with accompanying antagonistic effects) throughout the year
- Application of small quantities e.g. Borate, Kieserite or RP, results in inefficient use of labour, and at time poorly managed application (e.g. missed or over application of B)
- Therefore fertilization with straight fertilizers is very often an estate management nightmare.

Problem With Straights

Small window of time for fertilizer application



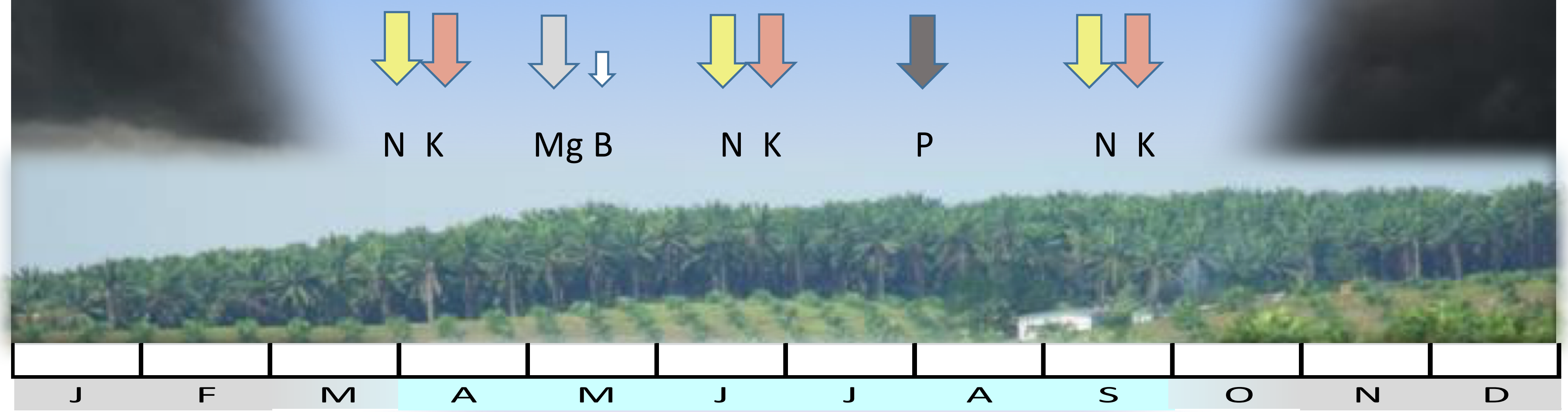
J F M A M J J A S O N D

Problem With Straights

Small window of time for fertilizer application

Use of straight fertilizers

9 rounds of straights in 6-9 months



Problem With Straights

Often delay in applications caused by

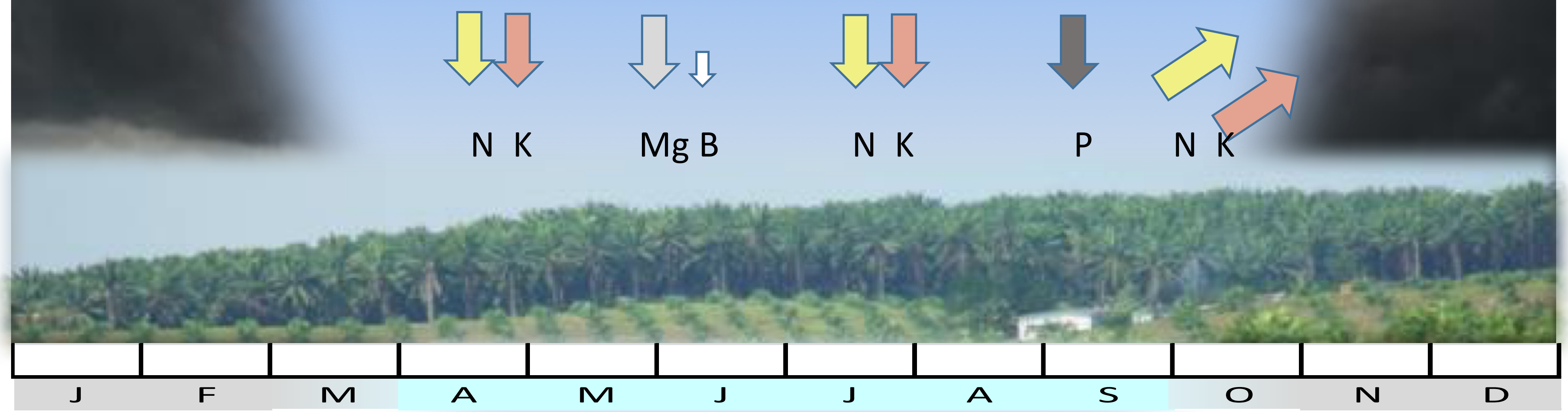
e.g. lack of labour, delay in delivery, weeding,

festive seasons etc

Inability to complete program

Carry-over to the next year

= under-fertilizing current year



"DELAYED" MANURING = UNDER FERTILIZATION

Under Fertilization leads to Reduced Yield

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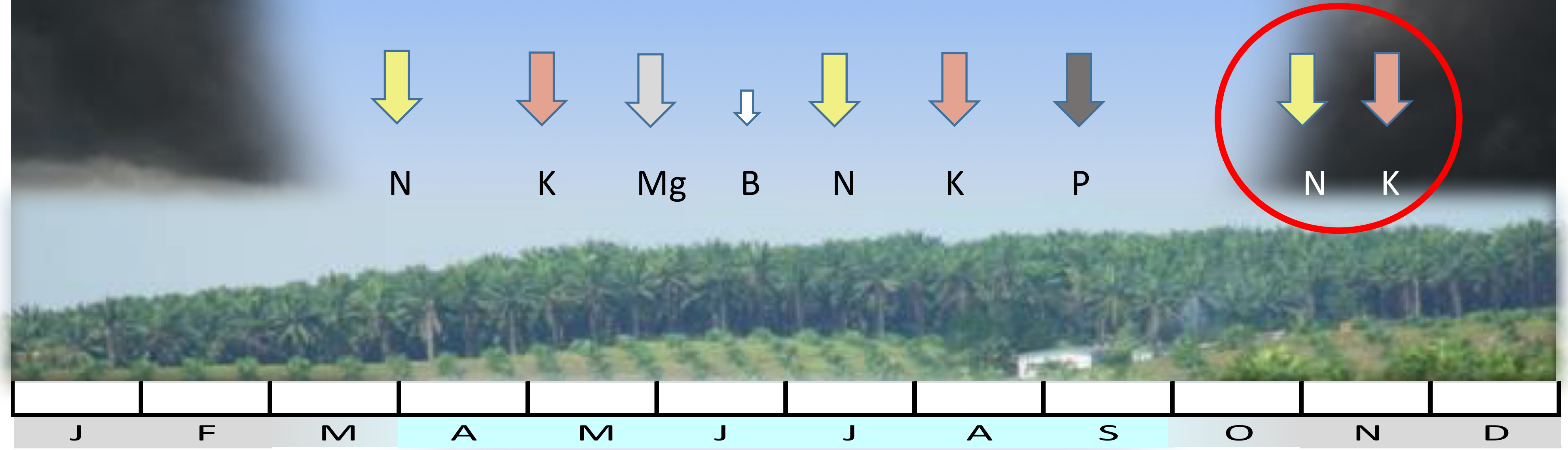
Problem With Straights

Small window of time for fertilizer application

Use of straight fertilizers

In order to achieve KPI

-> Fertilizers applied even in wet months

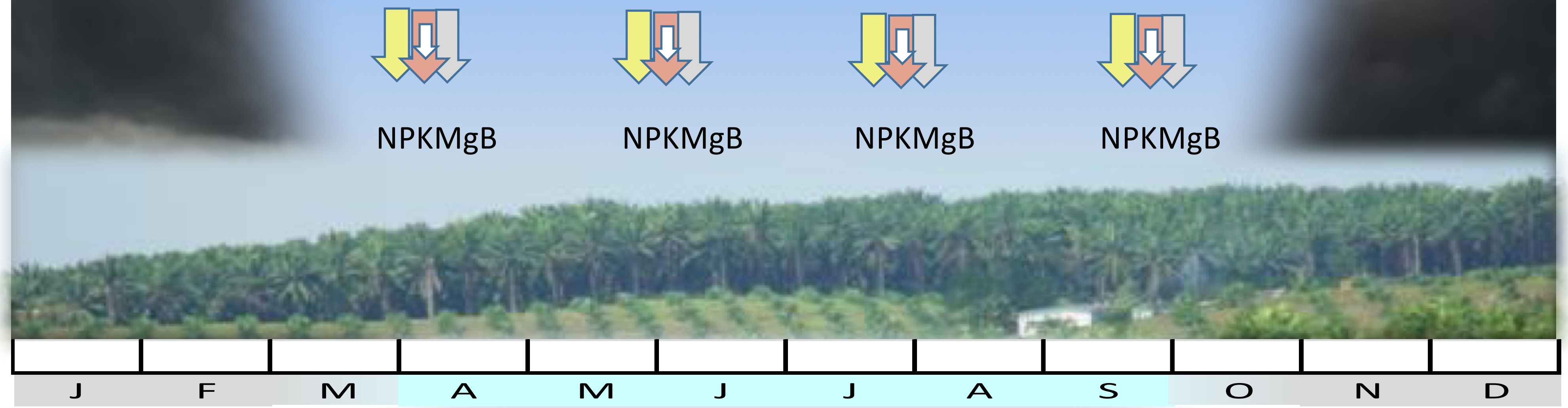


Using complete fertilizers (NPKMg+B) for oil palm

Reduced rounds of application

Borate with most rounds

Completion of fertilizer program



SOLUTIONS

- **Reduce the number of applications**
  - Increase the number of nutrients in each application
  - Use a complete nutrient fertilizer if possible
  - Use of controlled release fertilizer (nursery)
  - Use mulching (plastic) to reduce the number of rounds to one per year – especially for supply palms and high water-table areas (fast weed regeneration)

- **Change the method of application**
  - mechanical spreader (requires granular material)
  - furrow and apply?
  - sub-surface application?

- **Simplify your fertilizer program** *(next slide)*

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SOLUTIONS

Simplifying the fertilizer program

- After determining the nutrient inputs required, reduce the varied requirements of different fields to fewer groups (aero-nautical precision is not necessary here)
    - Remember the weakest chain is still the worker applying the fertilizer
- If your policy is max 4 applications per year, 2-3 common fertilizer rounds throughout the whole estate, plus 1-2 corrective rounds makes a sensible agronomist, and an effective plantation manager
    - Complicated fertilizer programs ties up scarce labor unnecessarily
    - Complicated fertilizer programs leads to incomplete fertilization, under-fertilization, and therefore reduced yields, period.

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CONCLUSION

The user is encouraged to understand the concepts of nutrients versus fertilizers; the conversion from one to the other; the nature of the various forms of nutrients and fertilizers; and then to use what is best for his circumstances.

The understanding of the different types of fertilizers and their properties can empower the user to choose prudently not just from the price per nutrient basis, but also on the basis of its effectiveness which may be affected, apart from its inherent properties, by the weather, soil type, etc. .

This is especially pertinent in oil palm where the cost of fertilization forms the single largest cost input, but is also the single biggest factor influencing yields.

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THANK YOU!

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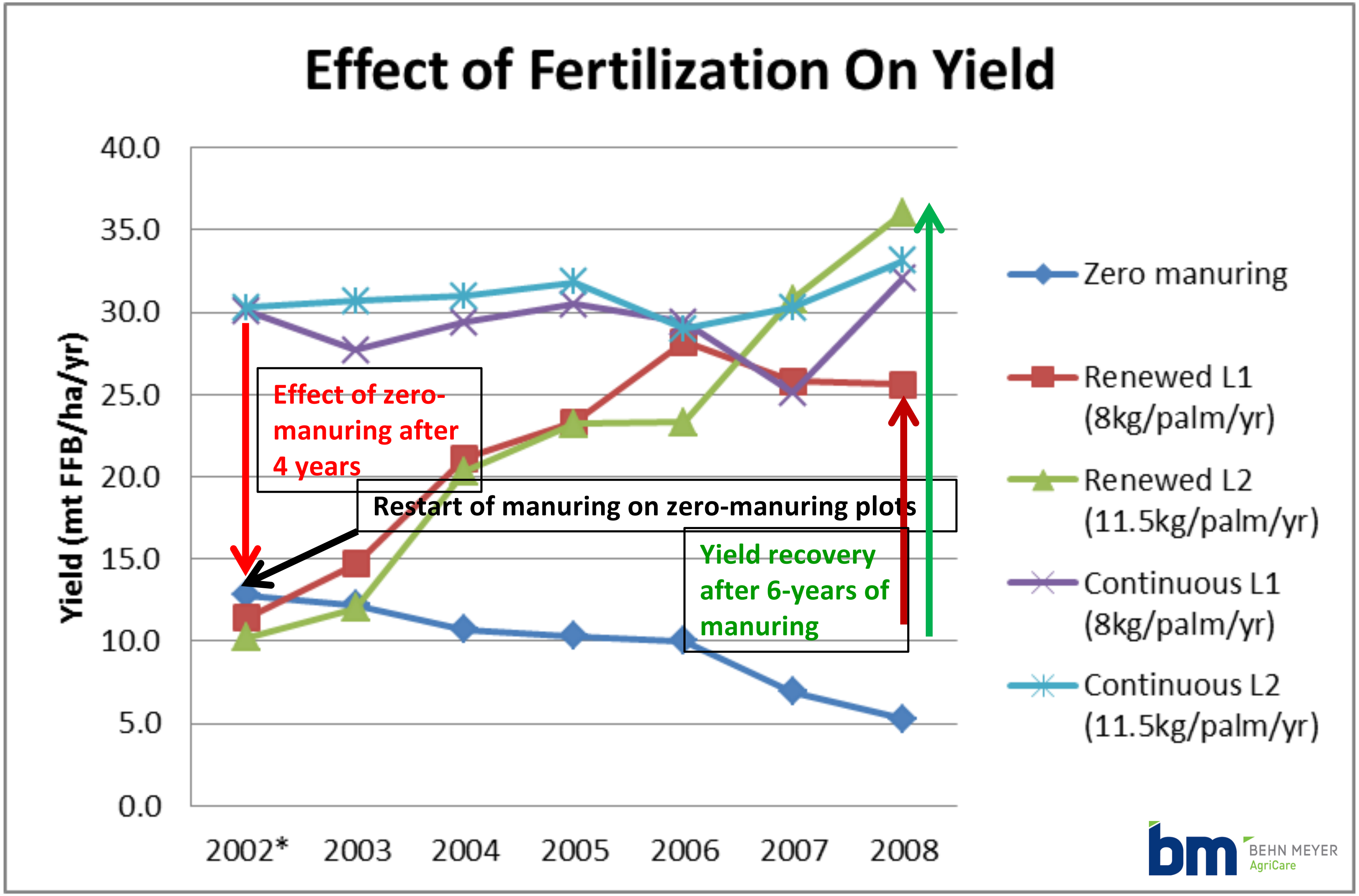
Effects of Fertilizer Application On Yield

Source: Manjit et al*, The Planter,84 (1004): 675-669 (2009)*



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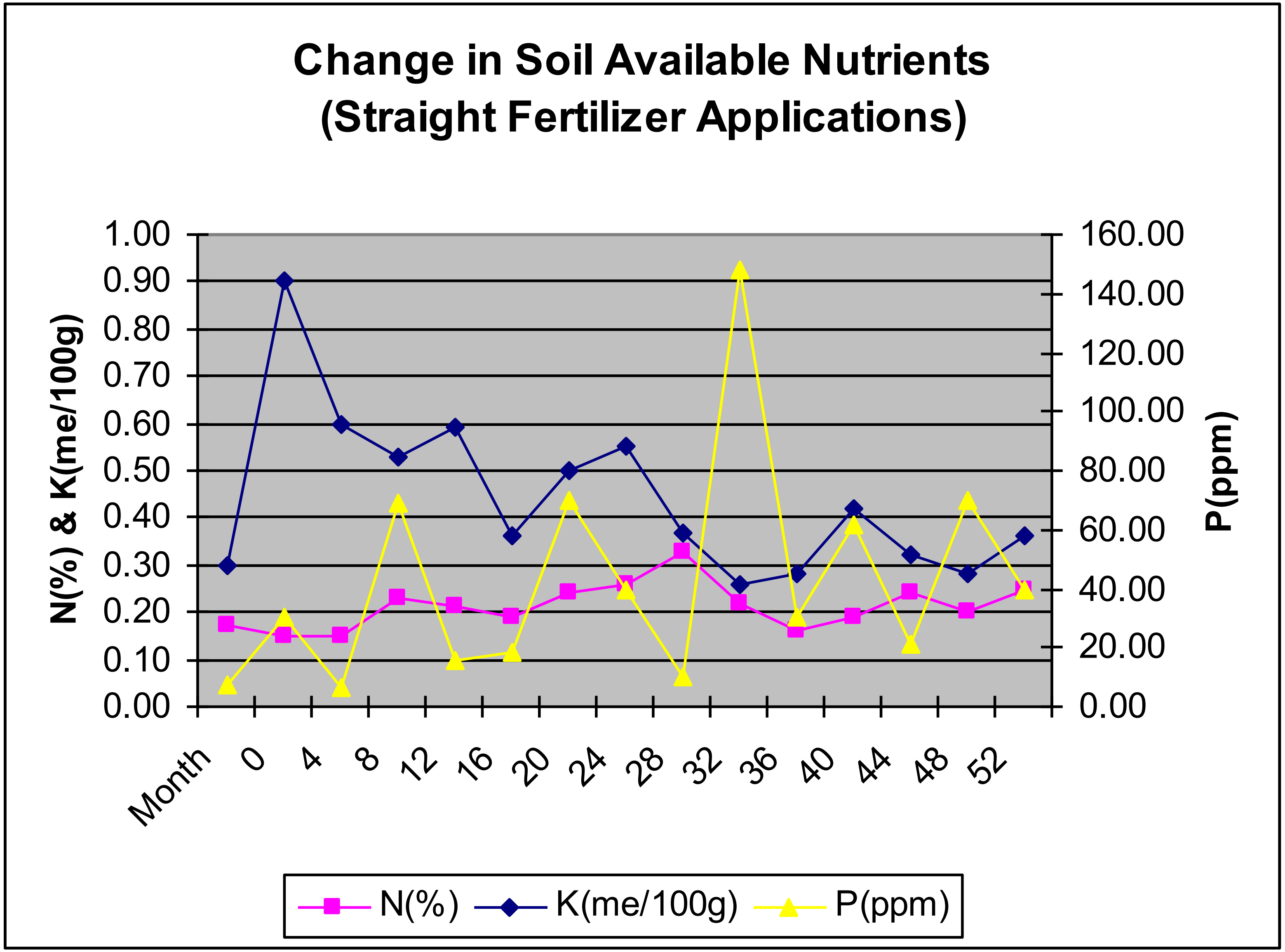
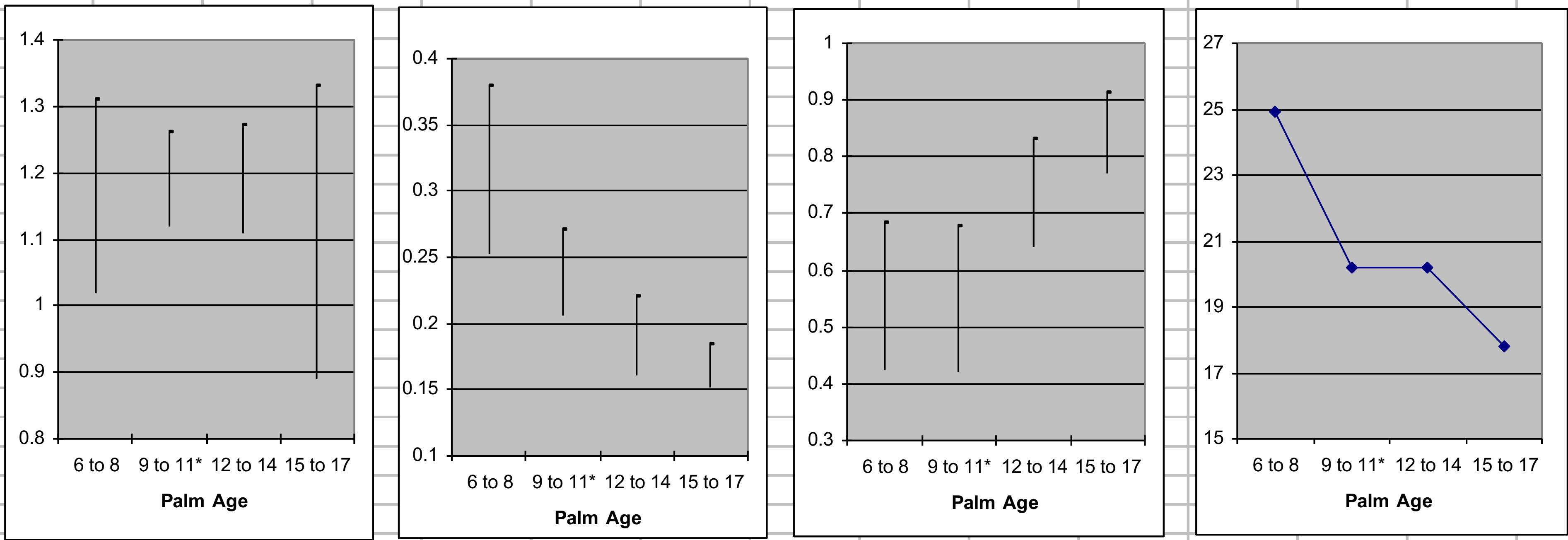
Nutrient Imbalances In The Soil



Potassium & Magnesium fertilizers

Effect of Dolomite on K, Mg and Ca Contents of Frond 17, and Yield Over 6 years

K% **Mg%** **Ca%** **Yield (t/ha)**



*** inception of GML Use**

Ng, Thong, Ooi & Leng, 1995

"Balanced Nutrition in Some Major Plantation Crops in S.E.Asia" - S.K.Ng, K.C.Thong, C.H.Khaw, S.H.Ooi and K.Y.Leng (24th Coloquium of the IPI, Chiengmai, Thailand)

Iron (Fe)

- The chemical form of a nutrient that is applied to the growing medium also affects solubility. A classic example of this is the iron form. The solubility of iron sulfate decreases rapidly as the medium pH increases above 5.5. Chelated forms of iron are soluble over a higher pH range, but this also depends on the type of chelating agent. The chelating agent, EDDHA, is highly soluble at pH 7.0, whereas the chelating agent EDTA is poorly soluble at the same pH.
- If iron deficiency is identified in a greenhouse crop, two questions should come to mind:
- Is iron present at sufficient levels in the growing medium (was it added to the substrate or present in the fertilizer program)?
- Is the iron available to be taken up by roots? Is the pH low enough for the iron form to be soluble? In many cases iron is included in the water soluble fertilizer program, but over time the medium pH becomes too high for the iron form to be soluble.

Sodium

- Plant scientists usually classify plant mineral nutrients based on the concept of "essentiality" defined by Arnon and Stout as those elements necessary to complete the life cycle of a plant. Certain other elements such as Na have a ubiquitous presence in soils and waters and are widely taken up and utilized by plants, but are not considered as plant nutrients because they do not meet the strict definition of "essentiality." Sodium has a very specific function in the concentration of carbon dioxide in a limited number of C 4 plants and thus is essential to these plants, but this in itself is insufficient to generalize that Na is essential for higher plants. The unique set of roles that Na can play in plant metabolism suggests that the basic concept of what comprises a plant nutrient should be reexamined. We contend that the class of plant mineral nutrients should be comprised not only of those elements necessary for completing the life cycle, but also those elements which promote maximal biomass yield and/or which reduce the requirement (critical level) of an essential element. We suggest that nutrients functioning in this latter manner should be termed "functional nutrients." Thus plant mineral nutrients would be comprised of two major groups, "essential nutrients" and "functional nutrients." We present an array of evidence and arguments to support the classification of Na as a "functional nutrient," including its requirement for maximal biomass growth for many plants and its demonstrated ability to replace K in a number of ways, such as being an osmoticium for cell enlargement and as an accompanying cation for long-distance transport. Although in this paper we have only attempted to make the case for Na being a "functional nutrient," other elements such as Si and Se may also confirm to the proposed category of "functional nutrients."

.

Sodium

1. Sodium is involved in the regeneration of phosphoenolpyruvate in CAM* and C4 plants. Sodium can potentially replace potassium's regulation of stomatal opening and closing.[5]
2. Essentiality of sodium: Essential for C4 plants rather C3
3. Na functions in metabolism - C4 metabolism
4. Substitution of K by Na: Plants can be classified into four groups:
    - Group A—a high proportion of K can be replaced by Na and stimulate the growth, which cannot be achieved by the application of K
    - Group B—specific growth responses to Na are observed but they are much less distinct
    - Group C—Only minor substitution is possible and Na has no effect
    - Group D—No substitution occurs
5. Stimulate the growth—increase leaf area and stomata. Improves the water balance
6. Impair the conversion of pyruvate to phosphoenol-pyruvate
7. Reduce the photosystem II activity and ultrastructural changes in mesophyll chloroplast
8. Internal osmoticum
9. Stomatal function
10. Photosynthesis
11. Counteraction in long distance transport
12. Enzyme activation
13. Improves the crop quality e.g. improves the taste of carrots by increasing sucrose

* **Crassulacean acid metabolism**, also known as **CAM photosynthesis**, is a carbon fixation pathway that evolved in some plants as an adaptation to arid conditions e.g. pineapples

Silicon

1. Silicon is not considered an essential element for plant growth and development. It is always found in abundance in the environment and hence if needed it is available. It is found in the structures of plants and improves the health of plants.
2. In plants, silicon has been shown in experiments to strengthen cell walls, improve plant strength, health, and productivity.[24] There have been studies showing evidence of silicon improving drought and frost resistance, decreasing lodging potential and boosting the plant's natural pest and disease fighting systems.[25] Silicon has also been shown to improve plant vigor and physiology by improving root mass and density, and increasing above ground plant biomass and crop yields.[24] Silicon is currently under consideration by the Association of American Plant Food Control Officials (AAPFCO) for elevation to the status of a "plant beneficial substance".[26][27]
3. Higher plants differ characteristically in their capacity to take up silicon. Depending on their SiO_2 content they can be divided into three major groups:
   - Wetland graminae-wetland rice, horsetail (10–15%)[citation needed]
   - Dryland graminae-sugar cane, most of the cereal species and few dicotyledons species (1–3%)[citation needed]
   - Most of dicotyledons especially legumes (<0.5%)[citation needed]

- The long distance transport of Si in plants is confined to the xylem. Its distribution within the shoot organ is therefore determined by transpiration rate in the organs[citation needed]
- The epidermal cell walls are impregnated with a film layer of silicon and effective barrier against water loss, cuticular transpiration rate in the organs.

Fertilizers As Sources Of Plant Nutrients

Introduction

Generally, it is agreed that there are 17 essential plant nutrient elements. Three major essential elements H, C, O, are obtained from atmosphere and water through photosynthesis. The other 14 essential mineral elements supplied by the soil, of which 12 are usually managed in agriculture through the use of fertilizers. These consists of the macro-nutrients (N, P, K, Mg, Ca, S), and the micro-nutrients (B, Cu, Zn, Fe, Mn, Mo). The other 2 are Cl & Ni. There are a few other elements, such as Na, Si, Se, V and Co, which are not essential, but may be beneficial to some plants either directly or indirectly.

Fertilizers are any solid, liquid or gaseous substances containing one or more plant nutrients. They are either applied to the soil, directly on the plant (foliage) or added to aqueous solutions (fertigation), in order to maintain soil fertility, improve crop development, yield and, or crop quality. Organic fertilizers are fertilizers derived from organic matter - animal matter, human excreta or vegetable matter (e.g. compost, manure). Inorganic fertilizers are those made from or containing material that does not come from plants or animals, and therefore exclude carbon-containing materials except ureas.

Main nutrients in oil palm

In oil palm as in many other crops, the main nutrients that are supplied as fertilizers are Nitrogen (**N**), Phosphorus (**P**) and Potassium (**K**). However, because of inherent soil deficiencies, as well as the high nutrient removal by the oil crop, the supply of other nutrients such as Magnesium (**Mg**), and Boron (**B**) are also often necessary. Other nutrient elements inputs such as Sulphur (**S**), Copper (**Cu**), Zinc (**Zn**), and Iron (**Fe**) may also be necessary for palms grown in certain soils.

N-Fertilizers

The commonly used N-fertilizers in Malayisa are ammonium sulphate (AS), ammonium chloride (AC), and Urea. Nitrogen is also present in some P-fertilizers such as di-ammonium phosphate (DAP) or other nitrogen phosphates (NPs). There are other less used N-fertilizers such as ammonium nitrate (AN), calcium ammonium nitrate(CAN), and ammonium sulphate nitrate (ASN).

P-Fertilizers

The most commonly used P source for oil palm has been ground rock phosphates because of the notion that these are the best sources for acidic soils of the region which are able to dissolve the otherwise water insoluble phosphate rock. The most commonly used materials in Malaysia today are from the Middle East, and these have a total P_2O_5 content of about 28%, and a citrate soluble P_2O_5 content of between 6 - 9%. For the P to become available to the palms, the phosphate rocks have to be finely ground in order to maximize the surface area of the particles for effective dissolution by the soil acids. Most materials imported today do not meet the SIRIM standards in their particle fineness. Practically, for the P to be available, it has to remain on the soil for a prolonged period due to its poor solubility. In reality, this may not be the case as heavy and intense rainfall often results in the undissolved particle being washed away with the other surface sediments in the water runoff. The use of more soluble forms of phosphorus fertilizers such as DAP, MAP or TSP warrants serious considerations both from an agronomic as well as economic stand-point.

K-Fertilizers

The K-fertilizer most commonly used in the country is potassium chloride (MOP). Other K-fertilizers used are Korn-Kali (K+Mg), Korn-Kali+B (K+Mg+B), and potassium sulphate (SOP). Korn-Kali fertilizers contain both MOP and Kieserite within each granule, and also Borate in the “+B” grades. SOP is used in chlorine (Cl) sensitive crops, whose quality or yield are affected by Cl, such as tobacco, citrus, tomatoes, coffee, potatoes and soybean. It is also recommended for crops grown on saline soils.

Mg-Fertilizers

Kieserite, the magnesium sulphate mineral, is the main Mg fertilizer used in the country. The synthetic form – magnesium sulphate is also used. Korn-Kali and Korn-Kali+B also contain Mg in a balanced proportion to K. Other magnesium containing materials such as dolomite and magnesite are not immediately soluble, and are used usually as liming materials, and are not as fertilizers for corrective applications.

B-Fertilizers

Until about twenty years ago, the very soluble sodium borate has been the only source of B used although it has been long established B is phloem immobile in oil palm. The small amount of between 100 – 150g of sodium borate per palm is applied in a single application a year. B from sodium borate is taken up in excessive levels immediately after application, and thereafter, the B availability in the oil is quickly reduced because of leaching losses. The phenomena of good frond-17 B-levels, despite deficiency symptoms showing, testifies to the inadequacy of this practice. The splitting of the B requirements of the palm into as many rounds as possible has been shown to be a far more effective way of supplying the micronutrient, and this is only possible when B can be incorporated into more rounds. The use of Korn-Kali+B, either as straight applications or as a component in bulk blends, is an example of how this is easily achieved. Less soluble but fully available forms of B, such as calcined Ulexite, are used in many countries throughout the world as a suitable source for B-immobile crops. This was introduced into oil palm some twenty years ago, and today, it is available as a straight fertilizer, or in combination with Kieserite which serves as carrier for the micronutrient and a Mg source as well.

Other micronutrients

The application of other micronutrients like Copper (Cu), Zinc (Zn), and Iron (Fe) in certain soils such as ultrabasic, deep peat or sandy soils may be necessary when deficiency symptoms occur. Common sulphates of the metal are the cheapest sources, and can be applied on the soil, as a foliar spray, or as incorporated in a mud ball. Chelated forms of these metals are also used as they are less easily fixed. They are more expensive, but the rates applied usually can be reduced because of the higher efficacy.

Sulphur

The Sulphur (S) status of soils in Malaysia and Indonesia has been studied very briefly by some. S is an important nutrient especially in oil producing crops, and is also a very easily leached nutrient in high rainfall areas. The prolonged use of non-S containing fertilizers such as Urea for N, and dolomite for Mg, may result in S-deficiency in the soil. S is usually needed in the same proportions as Mg, and thus Kieserite and Korn-Kali are ideal sources for S. Ammonium sulphate supplies large amounts of S as well.

Multi-nutrient fertilizers

Some plants, especially the annual crops such as rice, has different demands for the different nutrients at different stages of its development, and therefore the nutrient types and amount have to be timed accordingly. For perennial crops such as the oil palm which has a large trunk that serves as a reservoir of nutrients, the timing of fertilizer application is more dependent on the weather conditions. Typically, the total fertilizers per palm per year need to be split into at least 4 rounds. In most locations in Malaysia, the year-end monsoon period does not allow fertilizer application due to heavy leaching and run-off losses, and the fair to good weather months for fertilization per year may be limited to only about 8 months. As a result of this, many plantations find it difficult to apply many rounds of straight fertilizers, and the use of multi-nutrient fertilizers in the form of powder mixtures, granular bulk blends, or compound fertilizers becomes a necessary choice.

Fertilizer blends

Fertilizer mixtures or blends are the physical mixing of two or more fertilizer components to achieve a combination of various kinds – N-K, N-P-K, N-P-K-Mg, N-P-K-Mg+B, P-Mg, Mg+B, etc. When the components are all in granular form, it is called a granular blend. The components in a blend can segregate into less homogenous distribution as it is handled before use. Segregation occurs most when the components are not similar in size, resulting in the fine materials settling to the bottom of the packaging. Segregation is therefore less in granular blends, and within such blends, when the components are of similar granule size. A good blend can be achieved when the number of granular components can be minimized (e.g. to two or three), and be of similar proportions (e.g. 40:60, 50:50). Similarly, if a component is small (e.g. 5% of granular borate) compared to the rest, a good blend is harder to achieve.

Most fertilizers can be blended with each other, with varying compatibility. Poor compatibility usually involves reduced critical relative humidity, causing the mix to turn wet and physically unmanageable, e.g. urea with nitrate based fertilizers or single superphosphate.

Part of the work of the agronomist is to be able to derive the nutrient levels required for the various fields, and then to convert the straight requirements into equivalent mixtures. The use of at least two to three common blends for all fields, with one to two rounds of special blends or straights to correct for deficiencies is a most practical approach.

Compound fertilizers

Fertilizers can also be blended and then granulated to fix the nutrients and prevent segregation. The commonly used term for such fertilizers is to call it a compound fertilizer. Granulation can occur either by a wet-granulation process or a dry-granulation process. The wet-granulation process, as the name suggests, uses a wet-phase (urea-melt, or steam, or water, or combinations of the above) to cause granule formation. Drying is necessary after the granulation before the granules are sieved to obtain the desired size. In such a process, the binding of the components into individual granules with the desired proportions is hard to achieve, and the management of the hygroscopic nature of the urea is difficult. Products typically are more variable in analysis. In the dry granulation method, the components are accurately measured, mixed, and then compacted immediately in a hardened flake. The flakes are then broken down into smaller granules, and then sieved to get the desired product. Ideally, no wetting and drying is involved. Urea is seldom used in compaction granulation, so the associated problems are also avoided. Consistent product analysis is easier to achieve.

In evaluating a compound fertilizer, the nutrient percentages alone do not tell the full story. It is important to know what are the sources of raw materials used, e.g. source of N, solubility of P and Mg. It is also important to know the granulation process used to produce the fertilizer.

Complex fertilizers
The afore-mentioned compound fertilizers which are actually granulated blends, are not to be confused with a higher grade compound fertilizer, sometime referred to as complex fertilizers. These use either pipe-cross reactors to chemically melt NH_3, acids containing S or P, and other nutrients such as K and micronutrients into a granular fertilizer with a specific nutrient content, or use the nitrophosphate process involving the reacting of phosphate rock with nitric acid, and then adding other nutrient sources to achieve a complete formula. Such products achieve very high product consistency in analysis, and are also more expensive to produce.

Stabilized fertilizers
Stabilized fertilizers are those to which a N-stabilizer has been added in order to extend the time the N component of the remains in the soil in the urea-N or ammoniacal-N forms. Broadly, there are two types of N-stabilizers:

1. Nitrification inhibitors which inhibits the biological oxidation of ammoniacal-N to nitrate-N. This has the net effect of less leaching losses of nitrate-N, and higher uptake by plant of ammoniacal-N. Examples: DCD, DMPP
2. Urease inhibitors which inhibits the hydrolysis of urea by the urease enzyme. This can reduce volatilization losses, and increase N-uptake by the plants. Examples: NBPT, 2-NPT.

As environmental concerns are given more attention, the use of such fertilizes in more developed countries has gained importance. Fertilizers with the nitrification inhibitor DMPP are presently available in ENTEC, Novatec and Sato-Kali Special Plus fertilizers in Malaysia. Fertilizers with the urease inhibitor, UTEC, are also available.

Slow-release and controlled release fertilizers
Slow-release fertilizers are fertilizers which contain certain nutrient or nutrients that are released slowly into the soil due to its complex chemical structure. The nutrient is usually N, and examples are urea formaldehyde (UF), crotonylidene diurea (CDU) or isobutyledene-diurea (IBDU). The rate of release is slowed down, and depends on many factors such as the soil microorganisms, moisture content, and soil temperature.

Controlled release fertilizers are fertilizers containing water soluble nutrients, the release of which in the soil is controlled by a protective, water-insoluble coating applied to it. The duration of release is principally affected by the soil temperature, and can be controlled to a certain extent by the choice of coating material and its thickness. Nutrient release is achieved when osmotic pressure builds up within the encapsulated granules, resulting in dissolution, nutrient release, and lengthened duration of release. A blend of controlled release fertilizers of different release durations can be used to tailor the right amounts of nutrients to be released as desired over a period of say six to nine months. This is useful in certain conditions, e.g. poor manpower supply, fertilization of "supply" palms, poor accessibility areas.

Conclusion

Each of the fertilizer sources above, has its own characteristics, and understanding them enables the user to decide which to use, not just from the price per nutrient basis, but also on the basis of its effectiveness which may be affected, apart from its inherent properties, by the weather, soil type, etc. The user is encouraged to understand the concepts of nutrients versus fertilizers; the conversion from one to the other; the nature of the various forms of nutrients and fertilizers; and then to use what is best for his circumstances.

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Presented at the MEOA Lab Seminar 2016