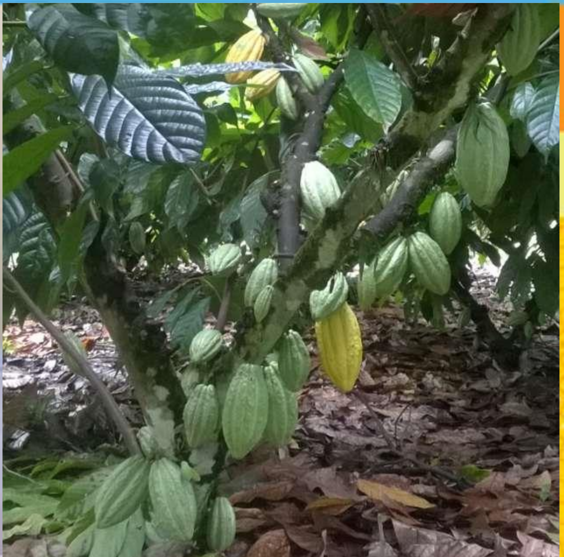
Knowledge grows

Assessing soil fertility and improving fertilization

Rolando Ureña
Commercial and Technical Manager
Emerging Markets



Why Fertilize?
Integrated Nutrition Program ....

Short term

Ensuring the availability of nutrients in each plant physiological event.

In the medium and long term

Control the evolution of soil fertility.

Integrated Nutrition Program ....

"Soil fertility is a dynamic process"

"Plants respond to the condition where they grow"

"Nutrition must adjust to changes Fertility"

"Excellent management programs may become obsolete"

Integrated Nutrition Program ....

It is based on the scientific analysis of thousands of historical data from the agricultural area crop.

Historical review of soil analysis, leaf and fruit of different production areas in the agricultural area of the country and the selected crop.

Morphological data generating during a long tem based on observation plots established in different farms of the crop in the country.

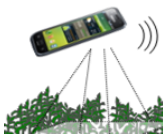
Quantification and statistics of performance of each harvest and the quality associated with nutrition.

Integrated Nutrition Soil, Crops and Ambient.

Crop Solutions

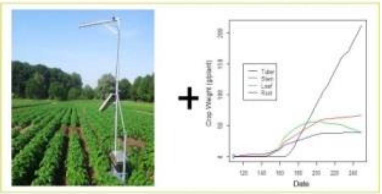
Precision Farming: It must be the future standard and must be commercially integrated to our solutions.

Data Collection → **Interpretation** → **Recommendation**



Digital tools and services:

- Nutrient and Water Sensors
- Soil, leaves and fruit analysis



Data Management.

RECOMMENDATIONS

KNOWLEDGE DEVELOPMENT

Data capture – Innovation and R&D – Partnerships – Compatibility

Tissue

- Foliar Analysis
- Stem Analysis
- Root Analysis
- Grain Analysis
- Fruit Analysis

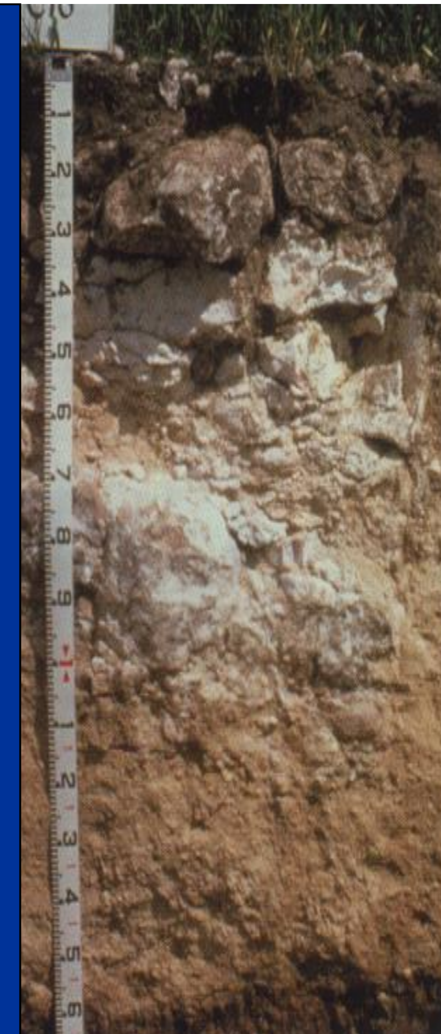
Leaf analysis of cocoa – nutrient contents in leaves of productive trees

N [%]	P [%]	K [%]	Ca [%]	Mg [%]	S [%]	source
2,0 – 2,5	0,1 – 0,3	1,3 – 2,2	0,3 – 0,6	0,2 – 0,5		Noordiana, 2007
1,8 – 2,2	0,1 - 0,12	0,4 – 1,3	1,7 – 2,2	0,6 – 0,9	0,14 – 0,2	Abreu, 1996
2,0 – 2,3	0,2 – 0,23	2,1 – 2,4	0,5 – 0,8	0,4 – 0,6	0,2 – 0,22	Malavolta,
2,34 – 2,4	0,21 – 0,23	1,6 – 1,7	0,8 – 0,9	0,4 – 0,45		Sodré, 2001
1,9 – 2,2	0,15 – 0,18	1,70 – 2,0	0,9 – 1,2	0,4 – 0,7	0,17 – 0,2	Bergmann, 1992

Fe [ppm]	Mn [ppm]	B [ppm]	Cu [ppm]	Zn [ppm]	source
60 - 200	50 - 300	25 - 70	8 – 12	20 - 100	Noordiana, 2007
33 – 64	242 – 435		6 – 9	32 – 75	Abreu, 1996
150 – 250	80 – 110	40 - 55	20 – 25	55 – 70	Malavolta,
63 - 83	194 - 226		39 - 44	116 – 130	Sodré, 2001
	150 - 200	30 - 40	10 - 15	70 - 80	Bergmann, 1992

Soil Analysis



Chemical Soil Analysis

- Content evaluation of SOLUBLE nutrients

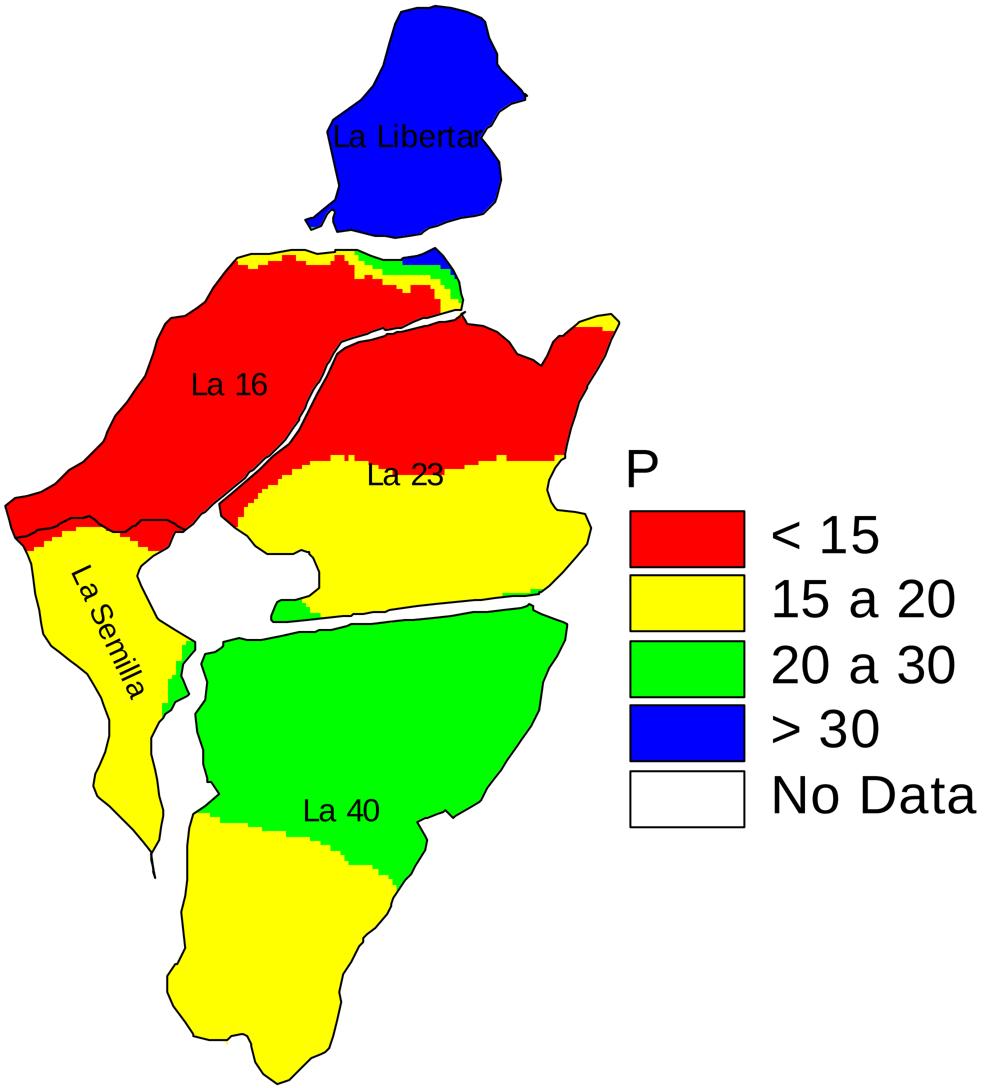
- Diferent extractive solutions:

• Acidity:	KCl Calcium Acetate pH 7 Aluminium
• Calcium, Magnesium, Potassium,Phosphorus :	KCl – Olsen Modified Melich 3 Interchangeable ion resins Saturated paste
• Micronutrients:	EDTA DTPA Warm water

- Relationship with variaty analysis-weather-soil-harvest tissue- quality

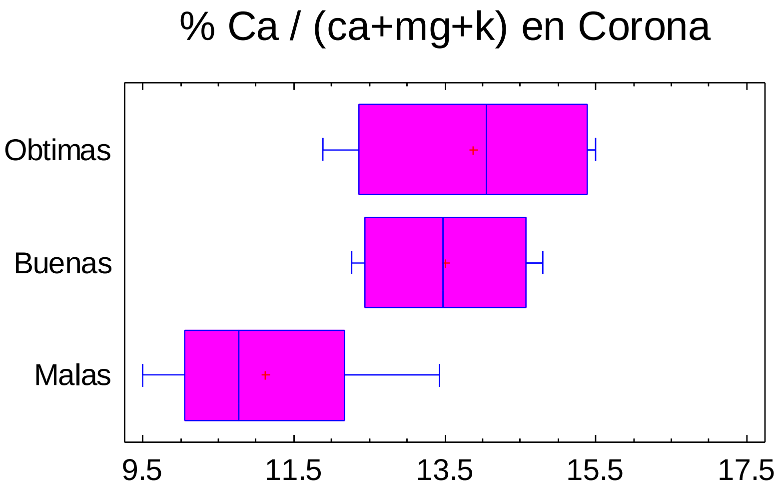
GPS farms are sampled and maps of soil fertility are built.

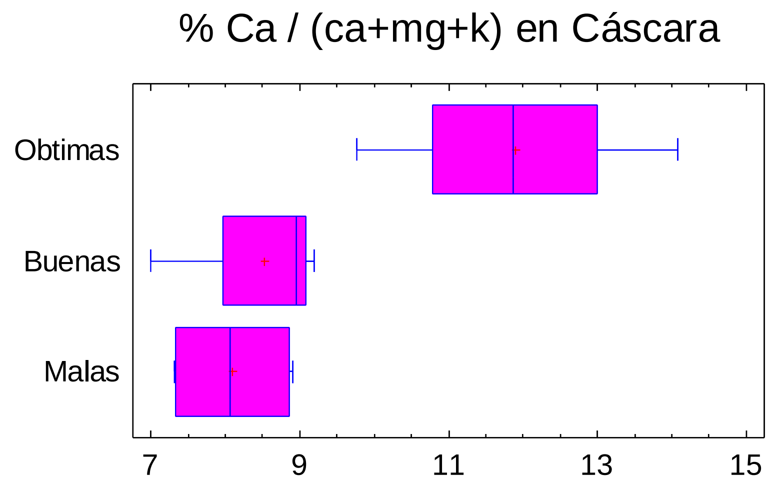
P (mg L^{-1})

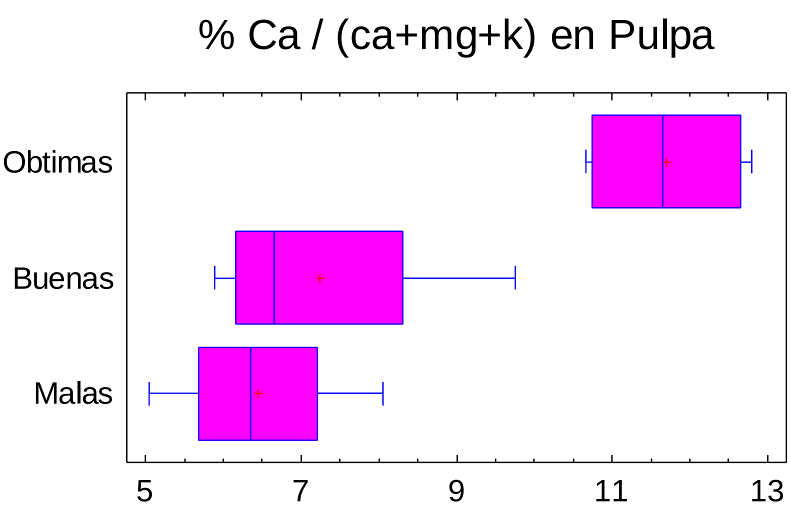


La Libertad
La 16
La 23
La Semilla
La 40
P
< 15
15 a 20
20 a 30
> 30
No Data

Fruit Analysis: Translucensy “water blow”


% Ca / (ca+mg+k) en Corona
Obtimas
Buenas
Malas
9.5
11.5
13.5
15.5
17.5


% Ca / (ca+mg+k) en Cáscara
Obtimas
Buenas
Malas
7
9
11
13
15


% Ca / (ca+mg+k) en Pulpa
Obtimas
Buenas
Malas
5
7
9
11
13

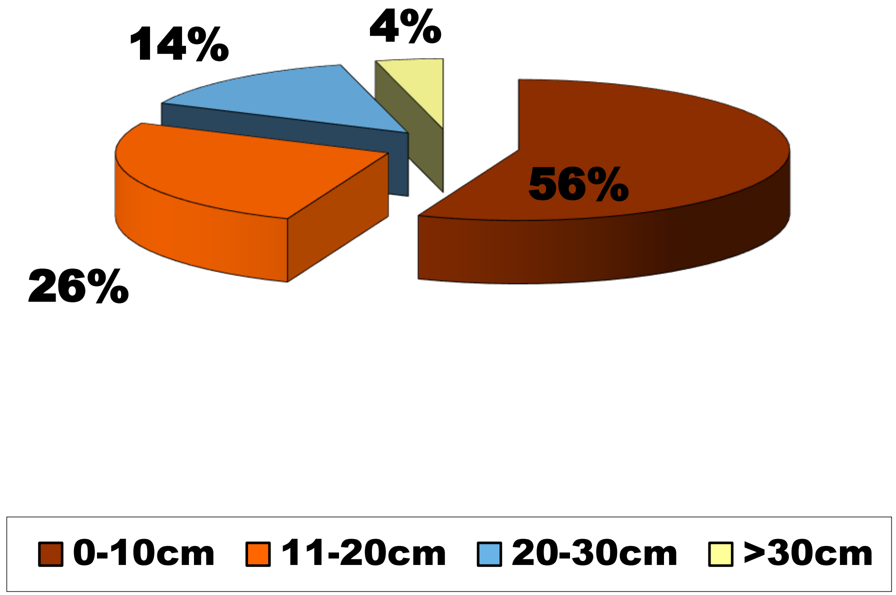
Why Production is Affected?

Fertile soil is needed for growth

- Leaves develop on cacao as groups or ‘flushes’.
- Leaves from one flush will mature before the next flush occurs.
- Nutrients for a flush of growth are drawn from the older leaves.
- If soil fertility is low, flush growth can cause major defoliation of the tree.
- Therefore the degree of defoliation during flush growth is often used as a guide to the soil fertility status.

Root depth

- Majority of the lateral roots are concentrated around the soil surface



source: Himme

Soil types

- Cacao prefers deep (at least 1.5m), well drained soils
  - Short term waterlogging is OK, but the roots must dry quickly
  - High water tables will limit root development
- Sandy clay loam to clay loam soils are highly productive
- Good organic levels are important
  - At least 3% organic matter
- Soil pH should be 5.0 to 7.0
- Production is severely limited below pH4.0 and above 8.0
- Cacao has low tolerance of Al toxicity

Soil Nutrition

Salinity

Salinity

- Cacao has a low tolerance of Chloride

- Care is needed when planting close to the seashore
  - Wind breaks are used to reduce wind blown seas spray from contacting the leaves

- Areas where the water table becomes seasonally saline (parts of Mekong Delta in Vietnam) can cause leaf burn during periods of higher salinity

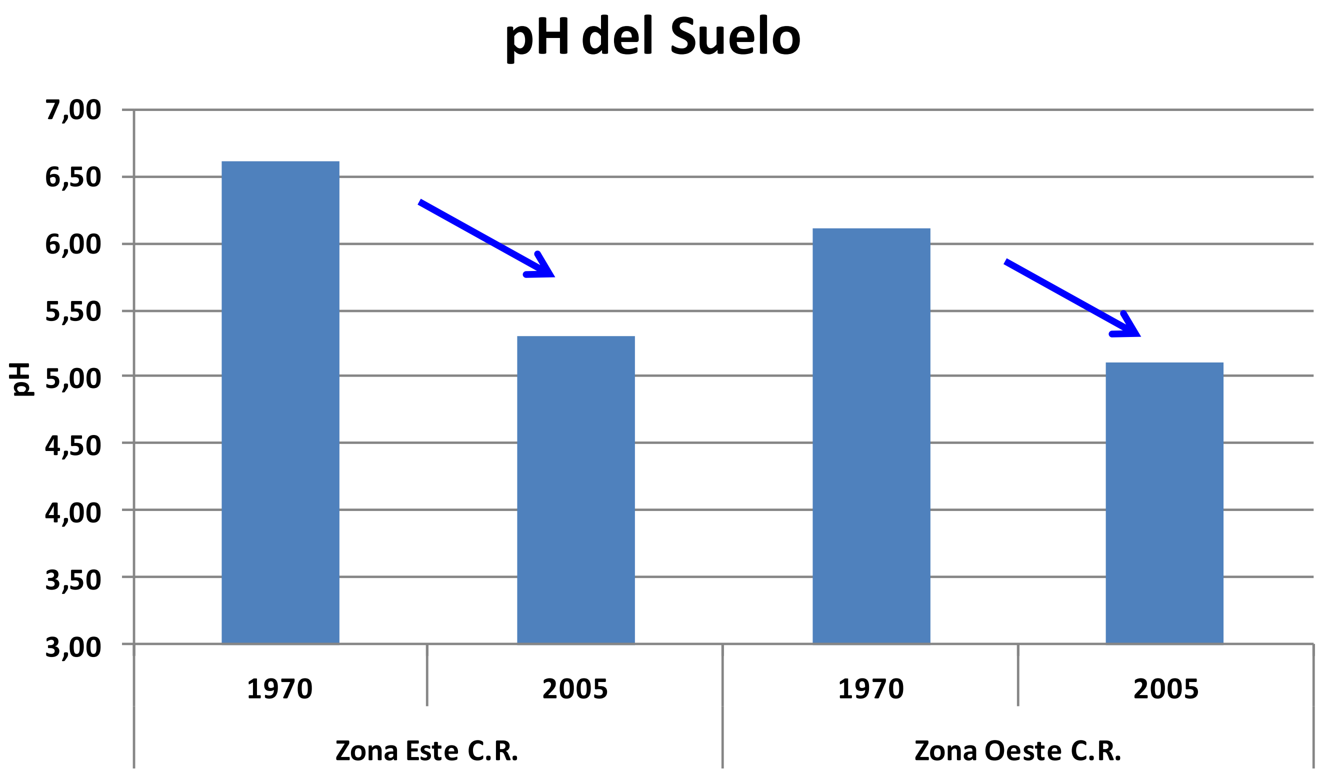
- Sulfate of potash fertilizers should be used in areas where chlorine levels are high.

Salinity lowers production

Soil Nutrition

Soil Acidity

Evolution of Soil Acidity in Costa Rica

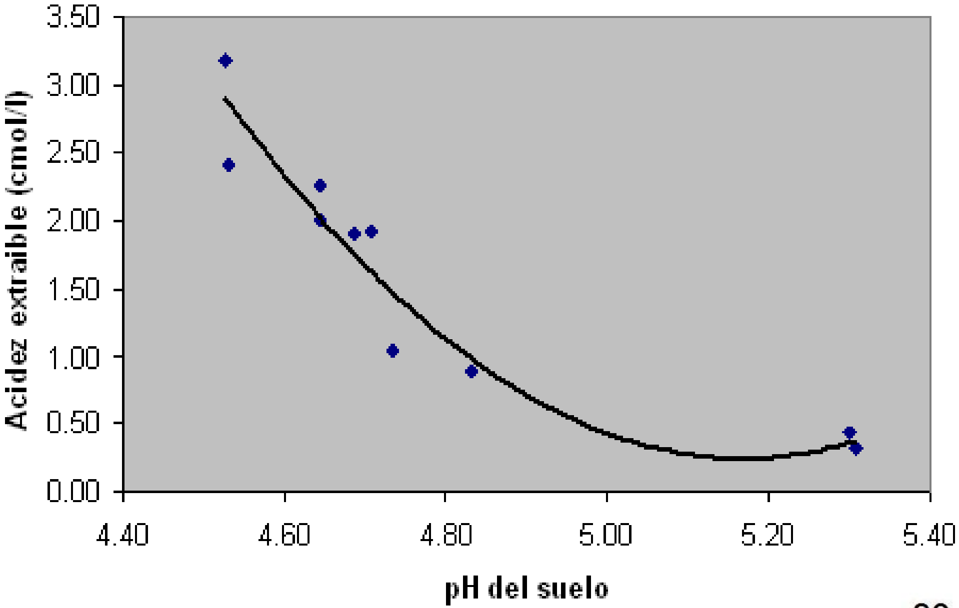


1970's sources:

$(NH_4)_2SO_4$
Urea

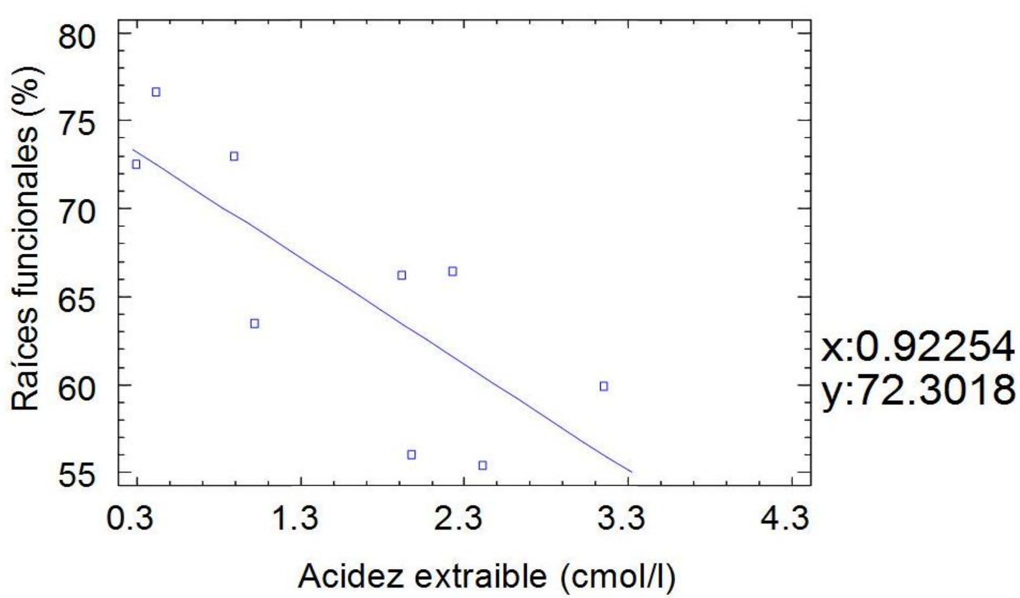
Regular applications for 700-800 kg N / ha / year, based on raw materials with high acidifying power for more than 30 years, have generated soil acidity. The subsequent formulation with more noble materials such as Nitrabor have allowed the reversal of malnutrition.

Effect of Soil Acidity on Root Growth



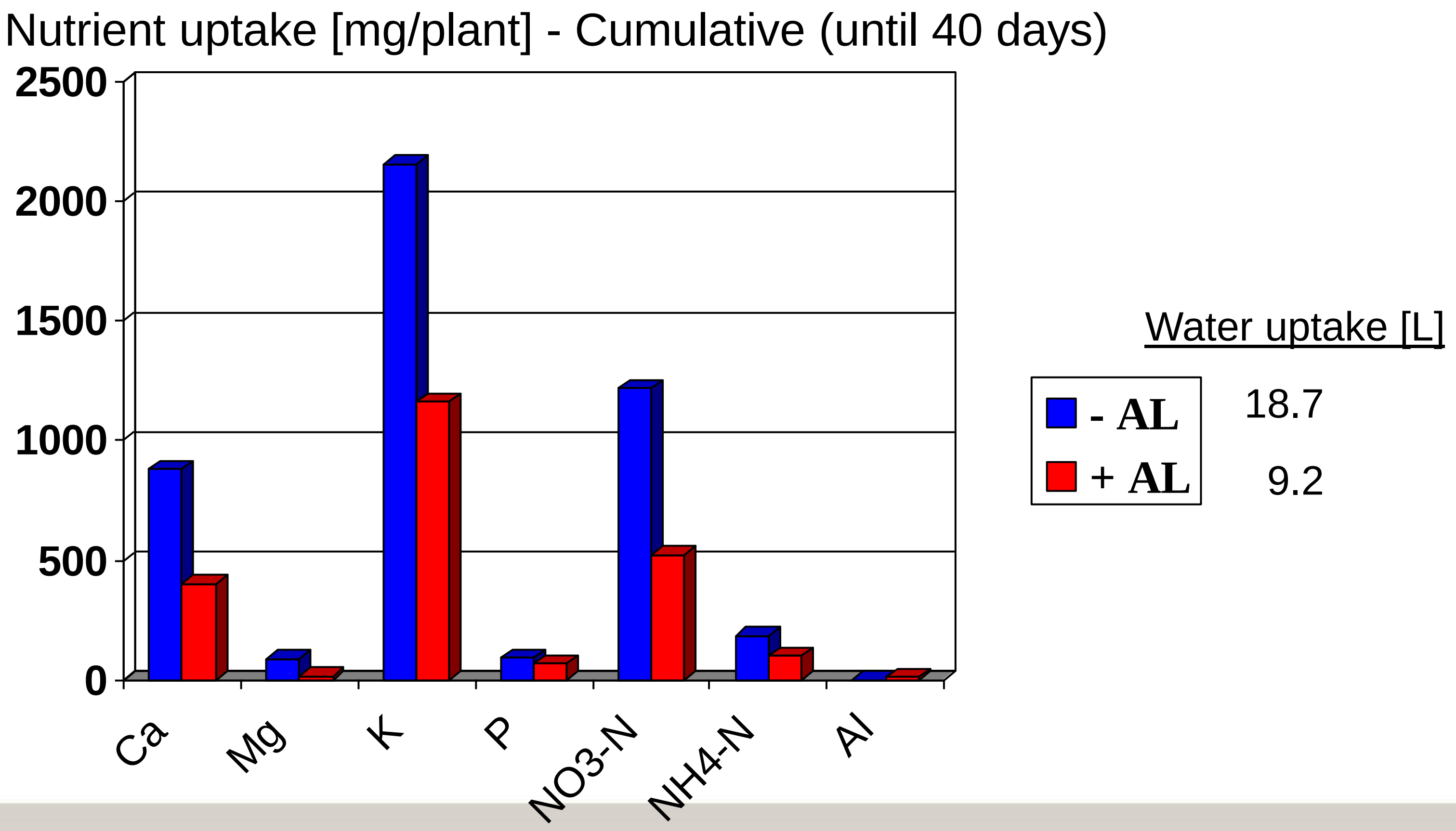
For its genesis tropical soils over time they tend to generate acidity. Years of using acidifying nitrogen sources have accentuated the problems of soil acidity.

Excess soil acidity accelerate the process of root mortality, favoring foliar deficiencies of Ca and Mg and the presence of physiological and nutritional disorders.



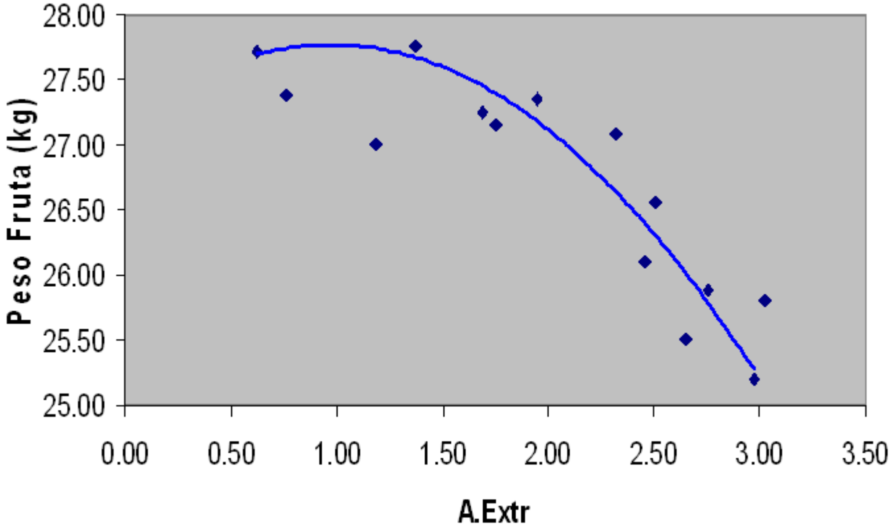
Banana :Problem on acid soils (low soil pH) Al toxicity reduces water and nutrient uptake by 50%

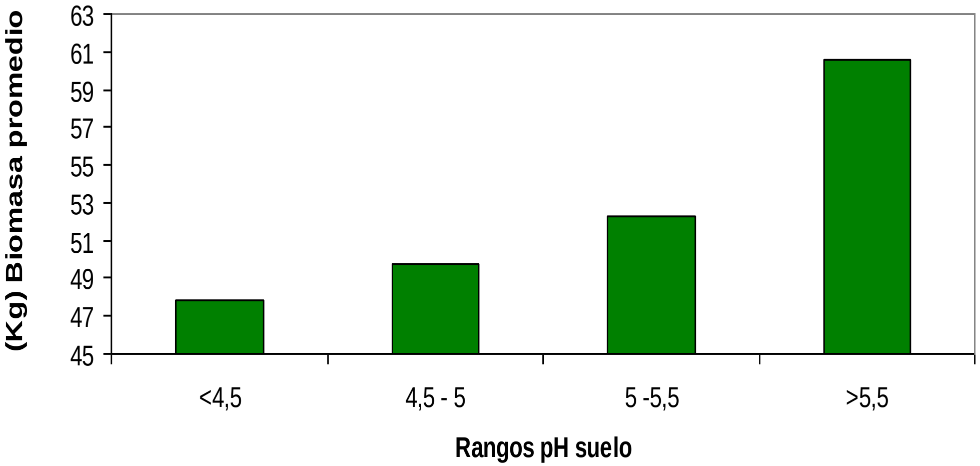
Grand Naine – Pot experiment (- and + Aluminium [2.2 ppm])



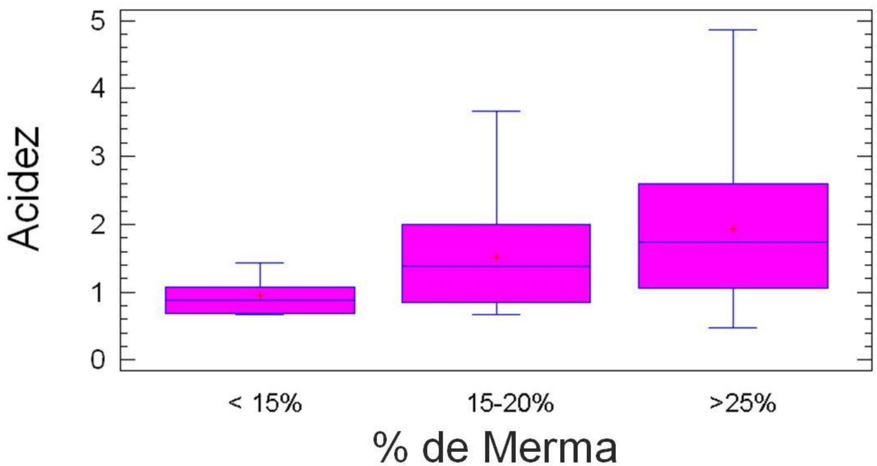
REF: Rufyikiri et al. (2000)

Effect of Soil Acidity in Weight and Quality Fruit



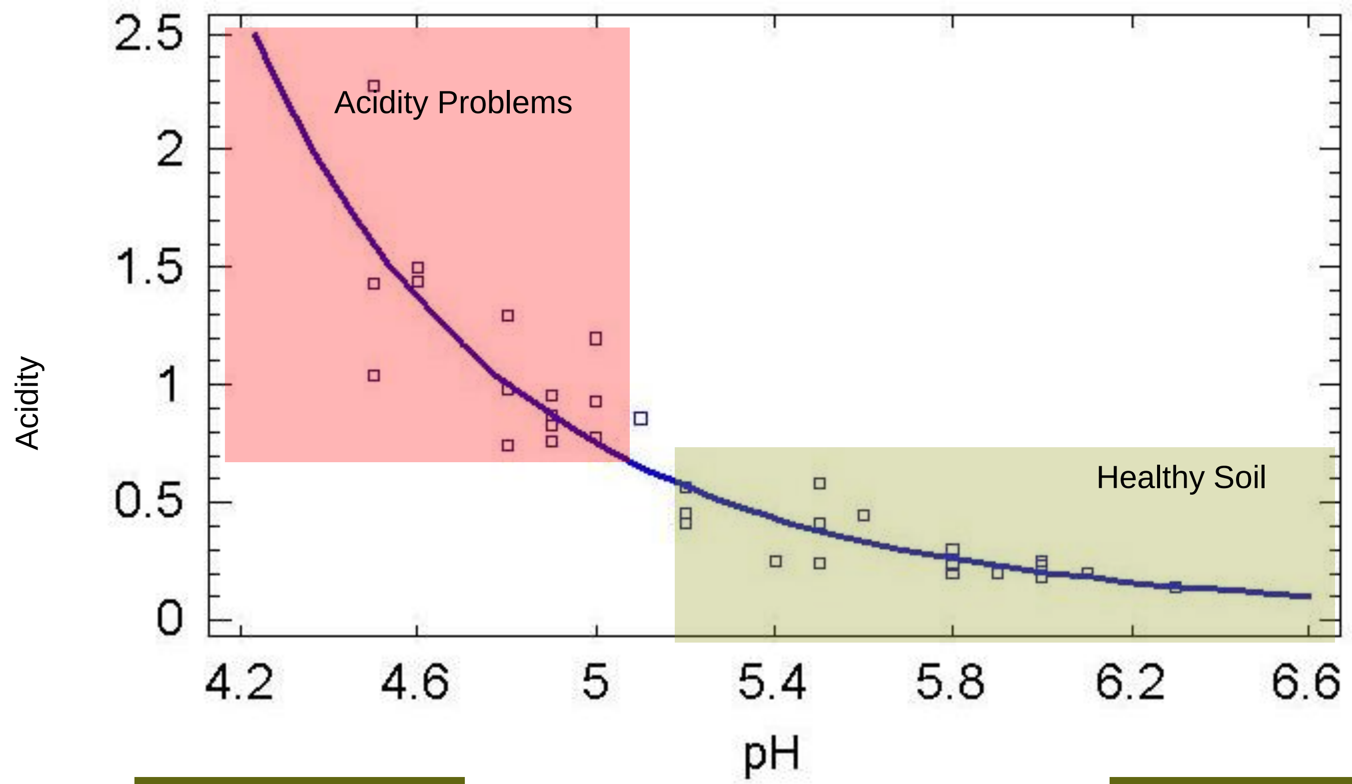


Exchangeable acidity facilitates the loss of roots in banana plant, one of the main effects is to reduce the weight of the bunch, due to lack of absorption sites of Ca, Mg and other nutrients.



There is a direct relationship between excess acidity and % of non-exportable fruit, because of nutrient deficiency as Ca.

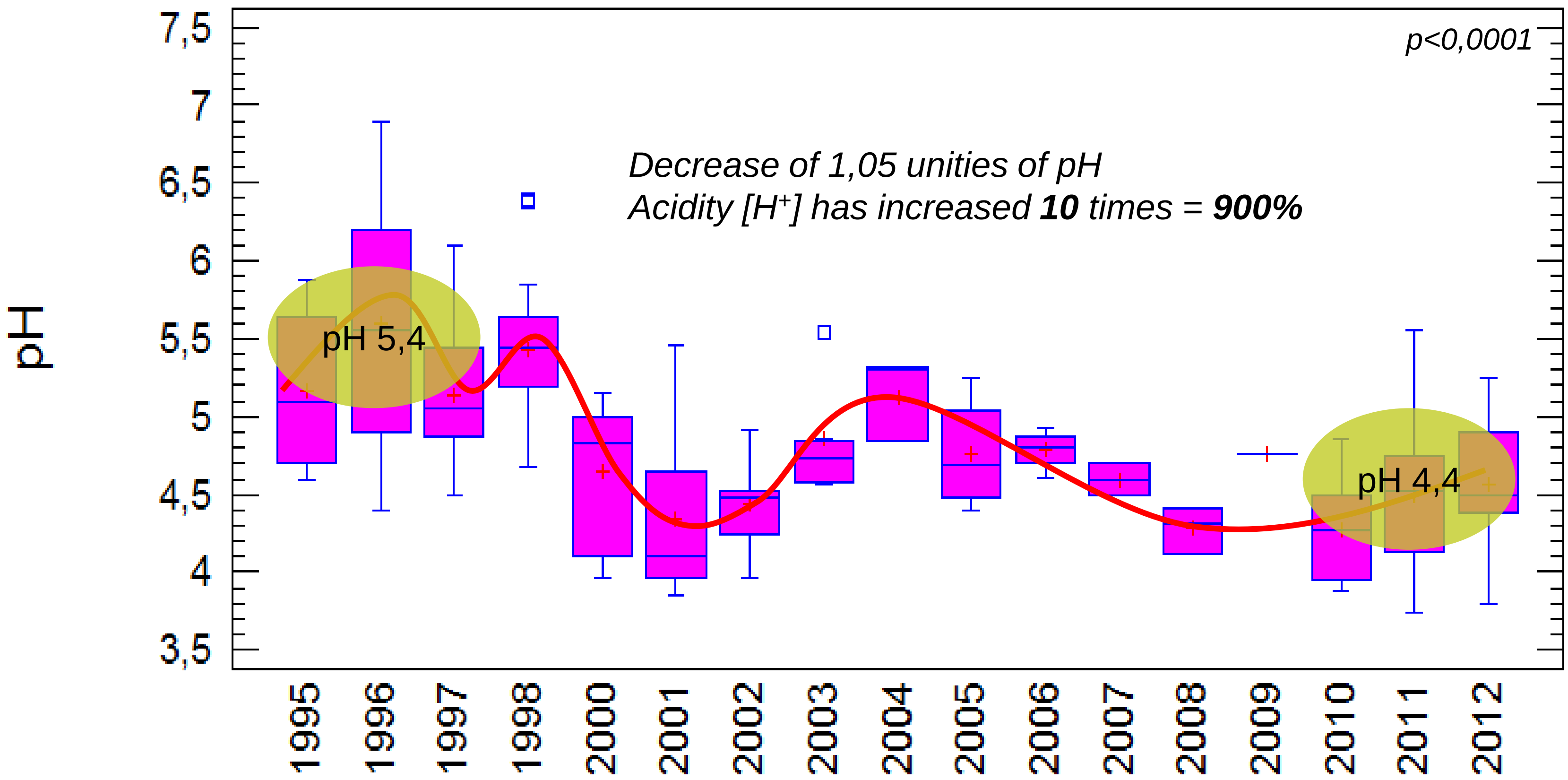
Relationship between pH and Soil Acidity in Coffee Farms in Costa Rica



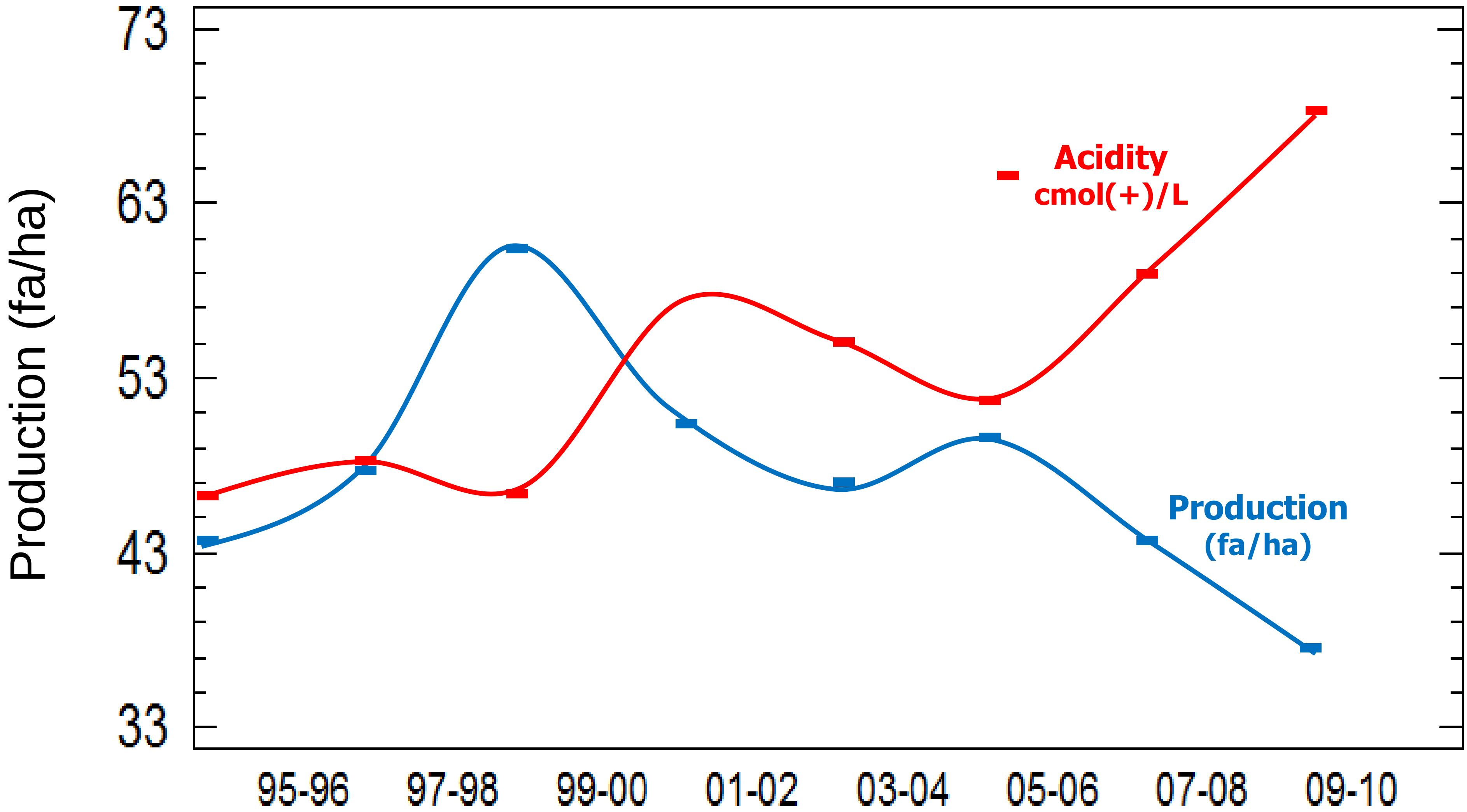
S.A. = 21 %

%S.A. = 8%

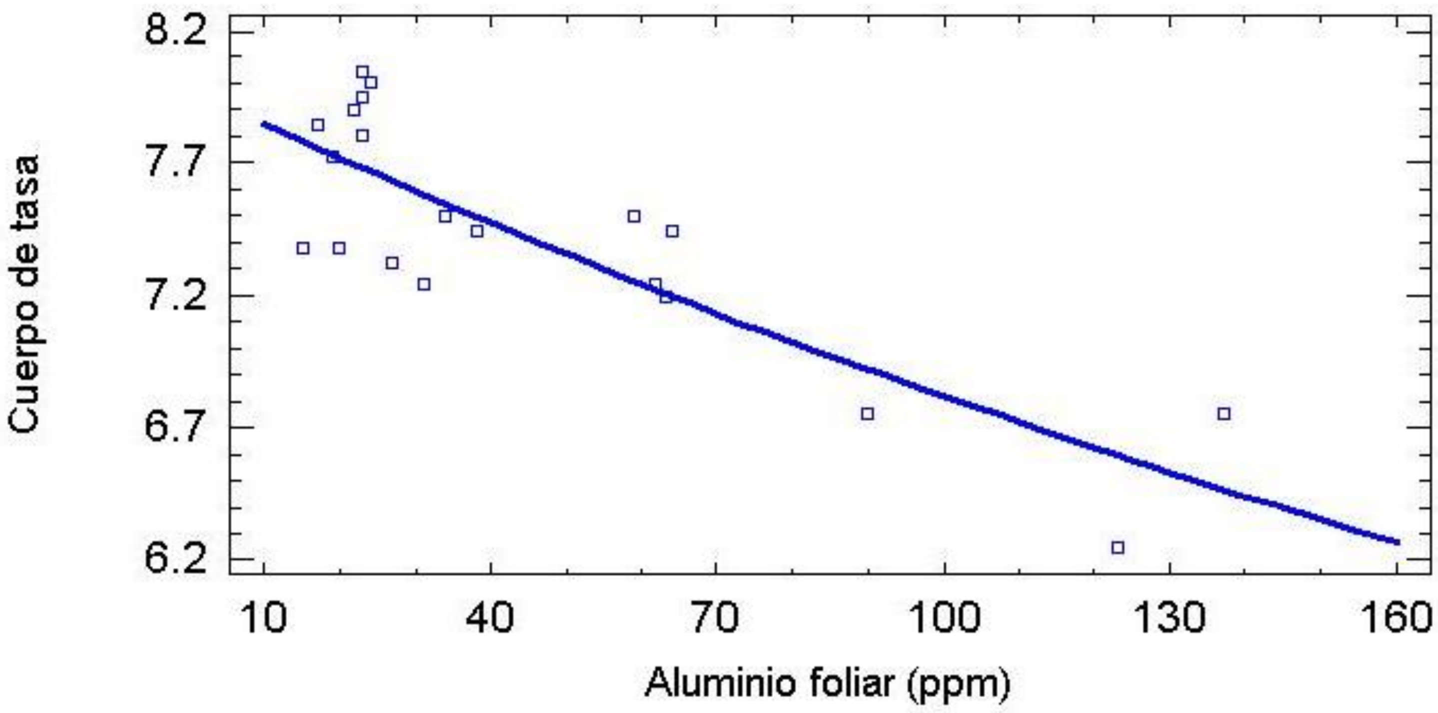
Soil pH Evolution in a Coffee Farm. Naranjo, Costa Rica



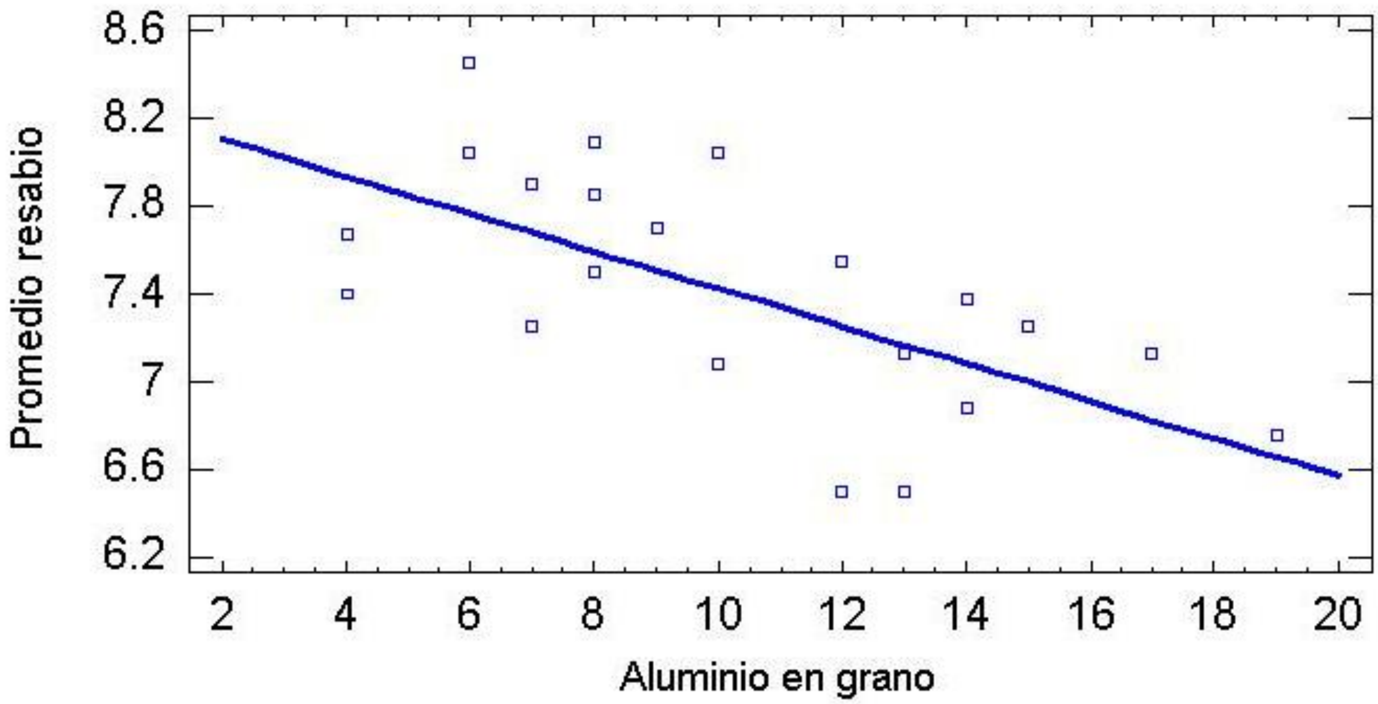
Relation of Soil Acidity and Production, coffe farm. Costa Rica



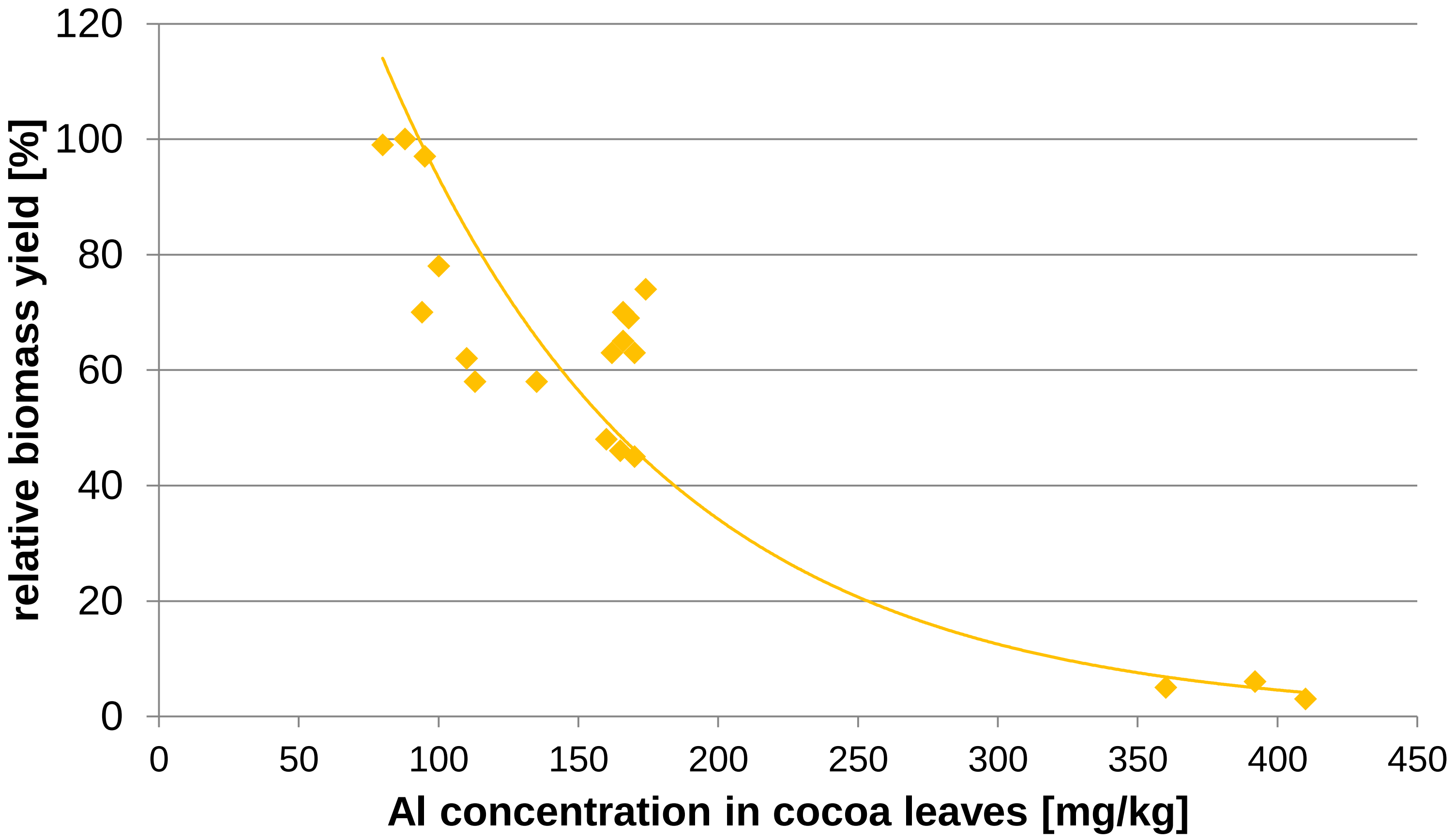
Relationship between the aluminum content in the leaf and the “cuerpo de tasa", Costa Rica



Relationship between the concentration of aluminum in the coffee bean and the “resabio de la tasa”, Costa Rica

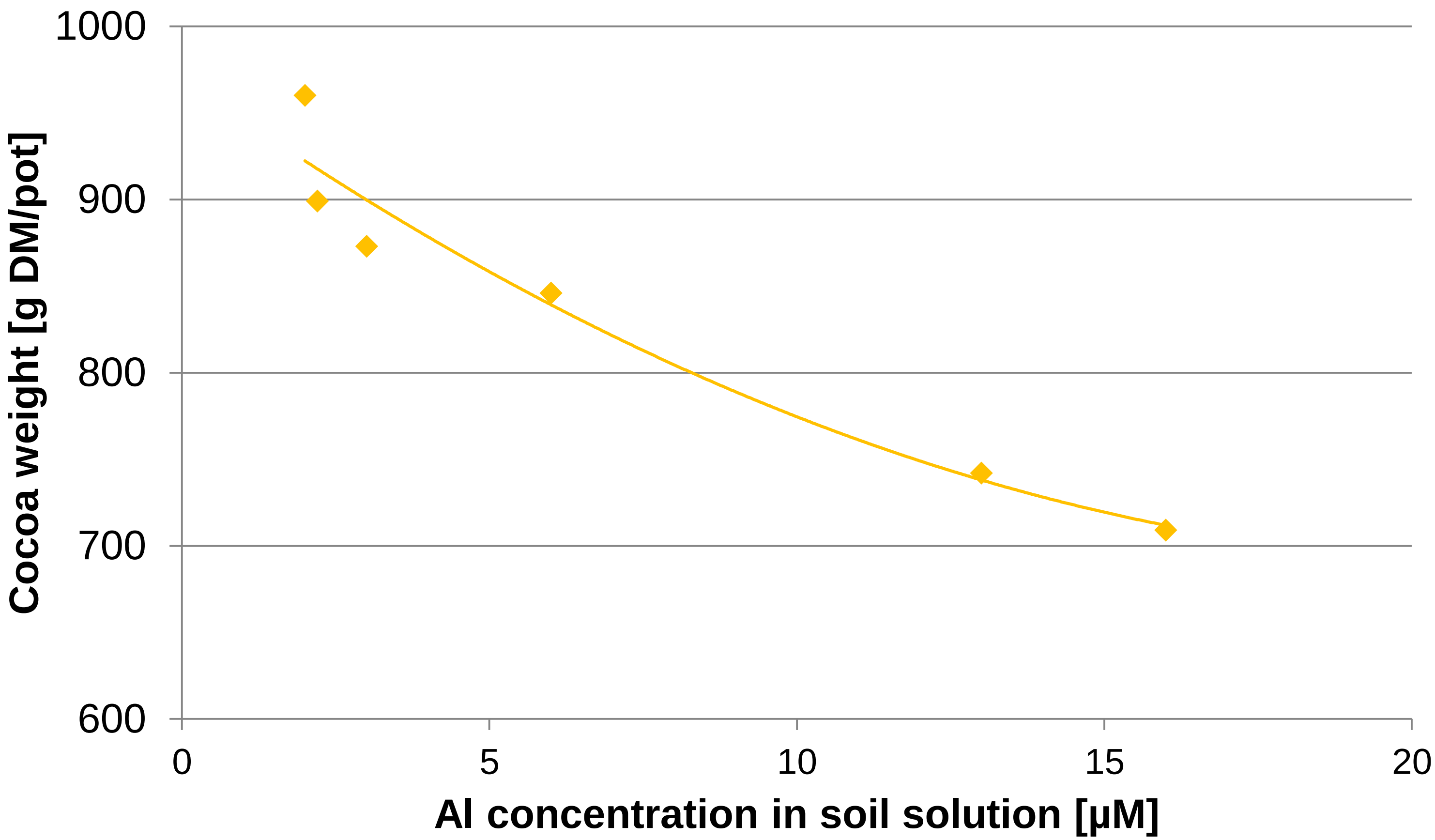


Effect of leaf aluminum concentration on growth of cocoa seedlings - Malaysia



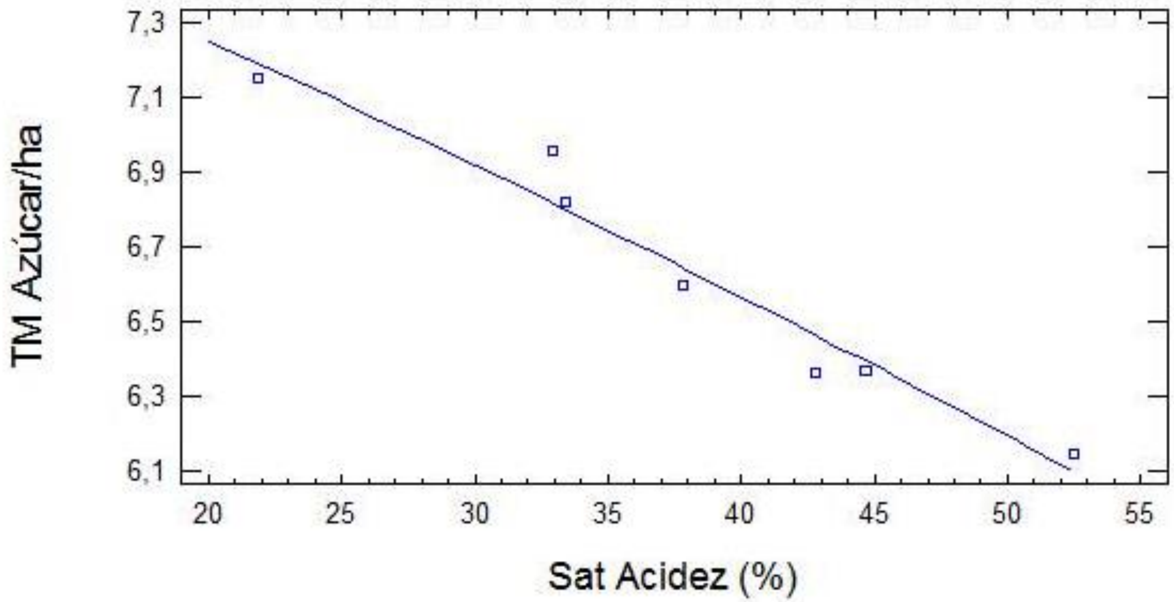
source: Shamshuddin, 2004

Effect of aluminum concentration in soil solution on growth of cocoa - Malaysia

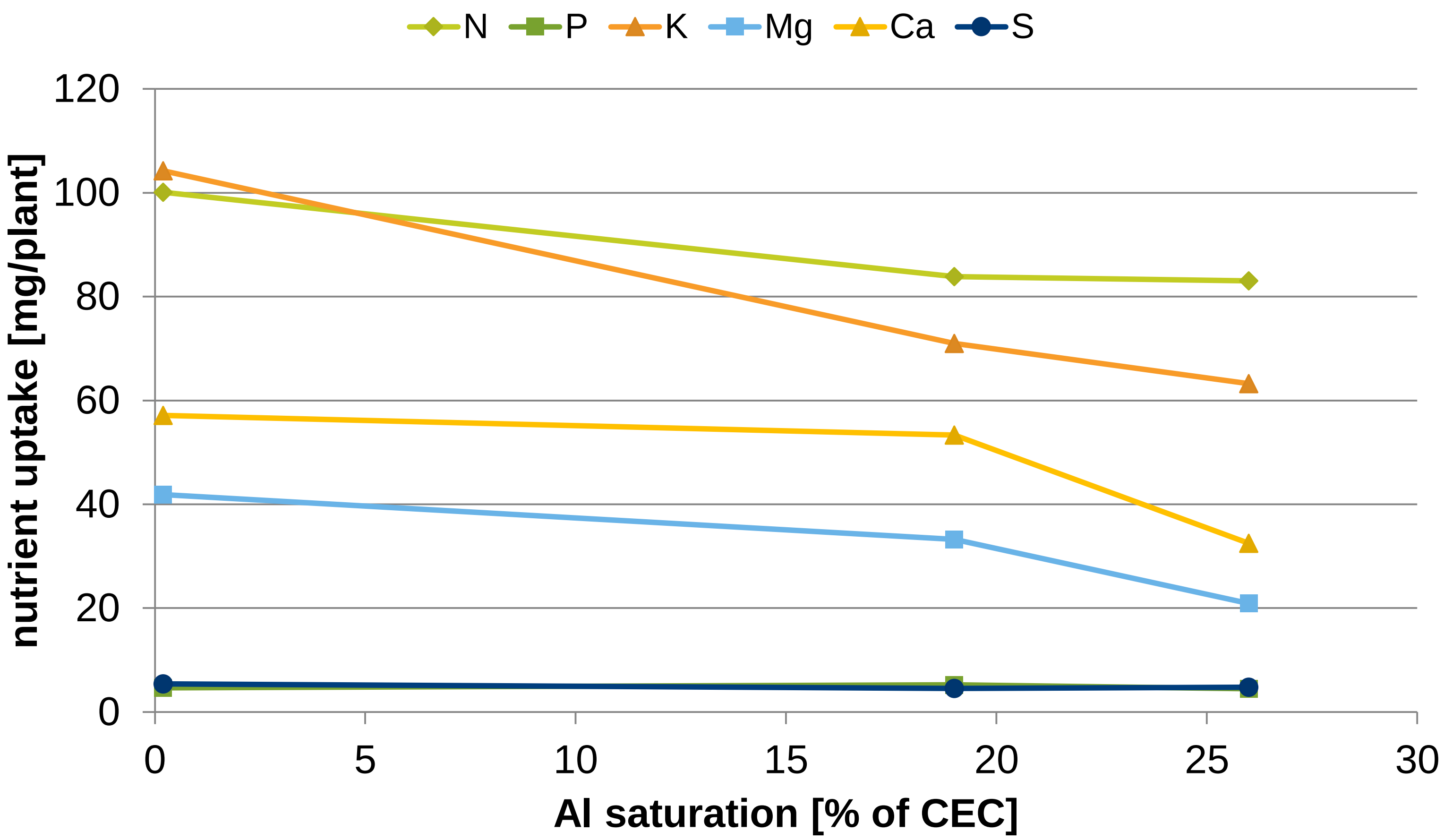


source: Shamshuddin, 2011

Effect of acidity saturation in the yield of Sugarcane



Effect of soil aluminum saturation on cocoa nutrient uptake - Brazil



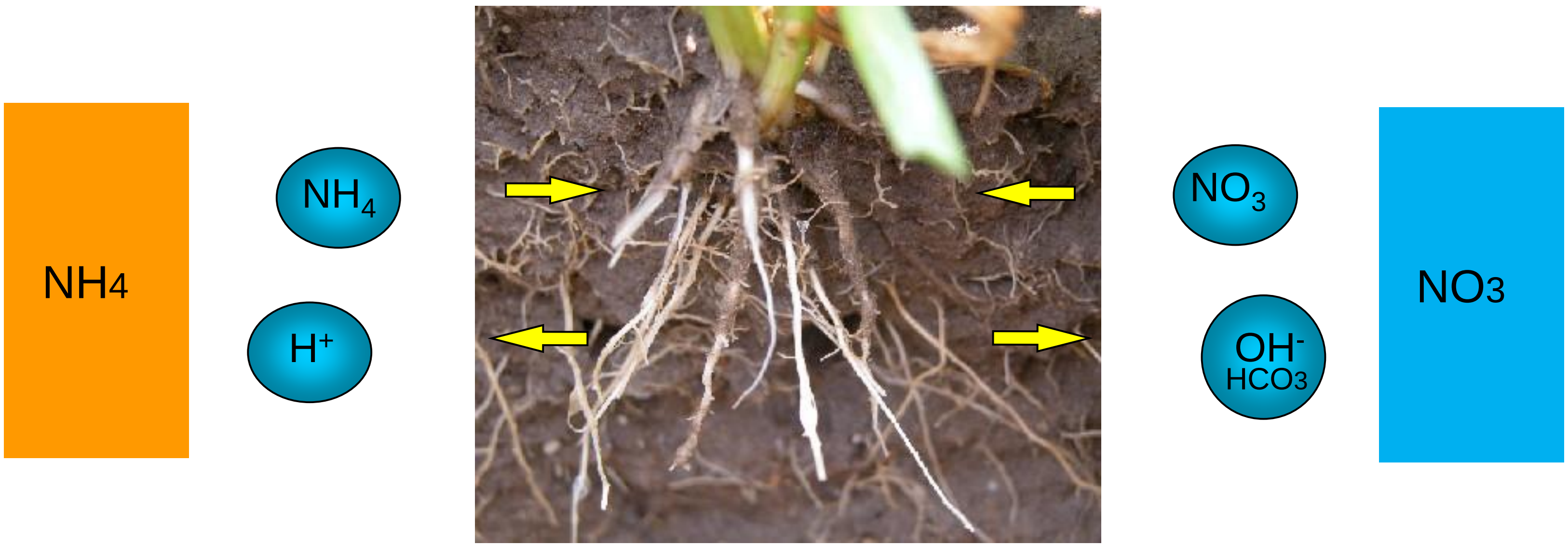
source: Baligar, 2005b

Acid Equivalent or Basicity of some Nitrogen Fertilizers

Fertilizer	% of N	kg $CaCO_3$/kg N	kg $CaCO_3$/100 kg mat.
Ammonium Sulphate	21	5,35 A	112 A
Urea	46	1,80 A	84 A
Ammonium Nitrate	33,5	1,80 A	63 A
MAP	10	6,5 A	65 A
DAP	18	4,1 A	74 A
Nitromag	21	0	0
Calcibor	15,5	1,7 B	27 B
Potassium Nitrate 13,5-0-44	13,5	1,9 B	26 B
Potassium Nitrate15-0-14	15	1,9 B	28 B

Adapted from Tisdale et al, 1993

Effect of Nitrogen Source in Soil pH



pH decreases

++ Acidity

pH increases

- - Acidity

Effect of the Nitrate in Soil pH

Nitrate-N increases root zone pH

Ammonium-N decreases root zone pH
(NH_4^+ in, H^+ out)

16.6 mgNO_3-N

16.6 mg NH_4-N

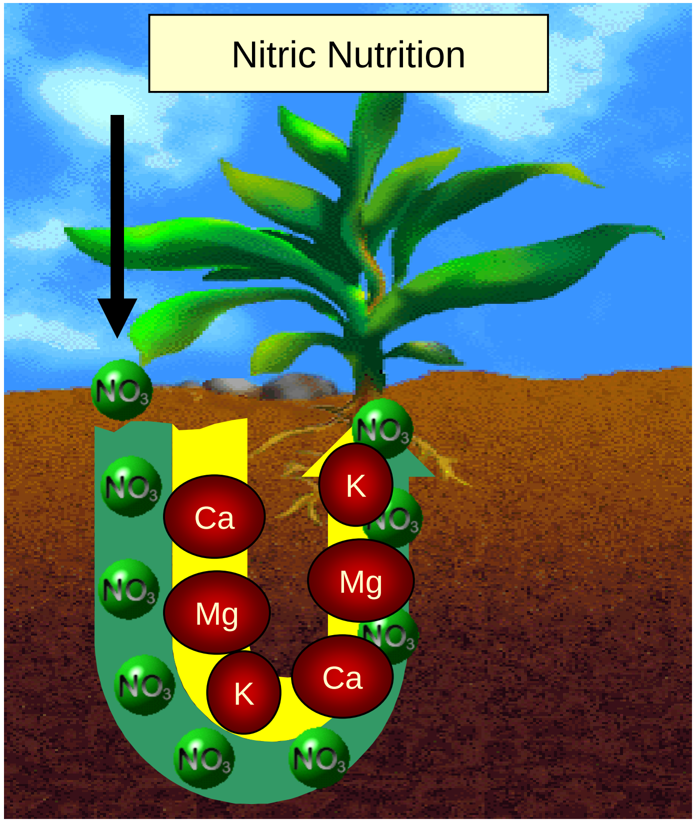
Ammoniac Nitrogen acidifies the rhizosphere: $NH4^+$ enters, H^+ leaves

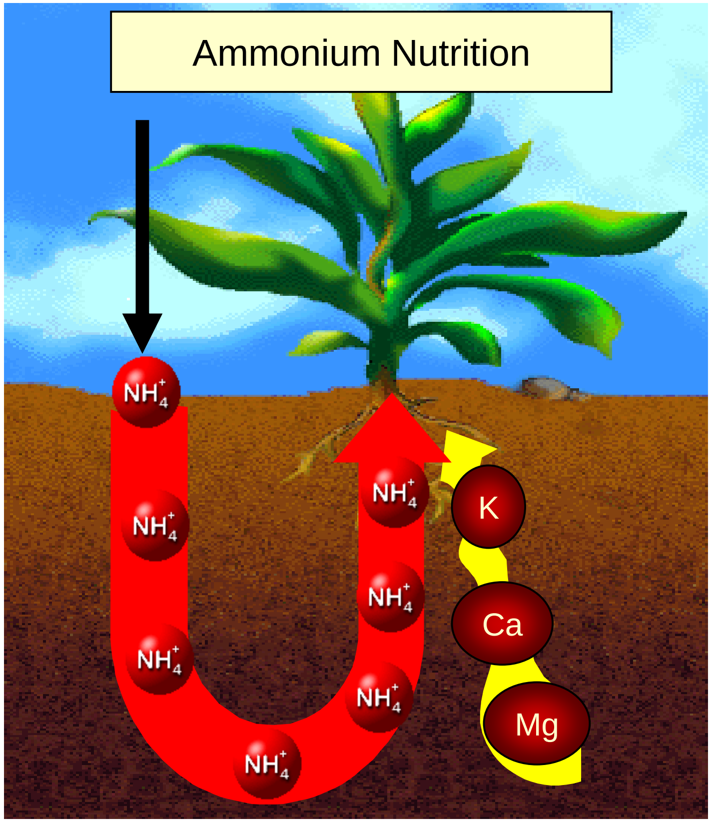
Nitric Nitrogen increases the pH in the rhizosphere: : NO_3^- enters, OH^- leaves

Marschner & Romheld, 1983

Synergisms and antagonisms between Nutrients

- ✓ Nitrates carry cations to be absorbed.
- ✓ Ammonium absorption competes with the absorption of other cations

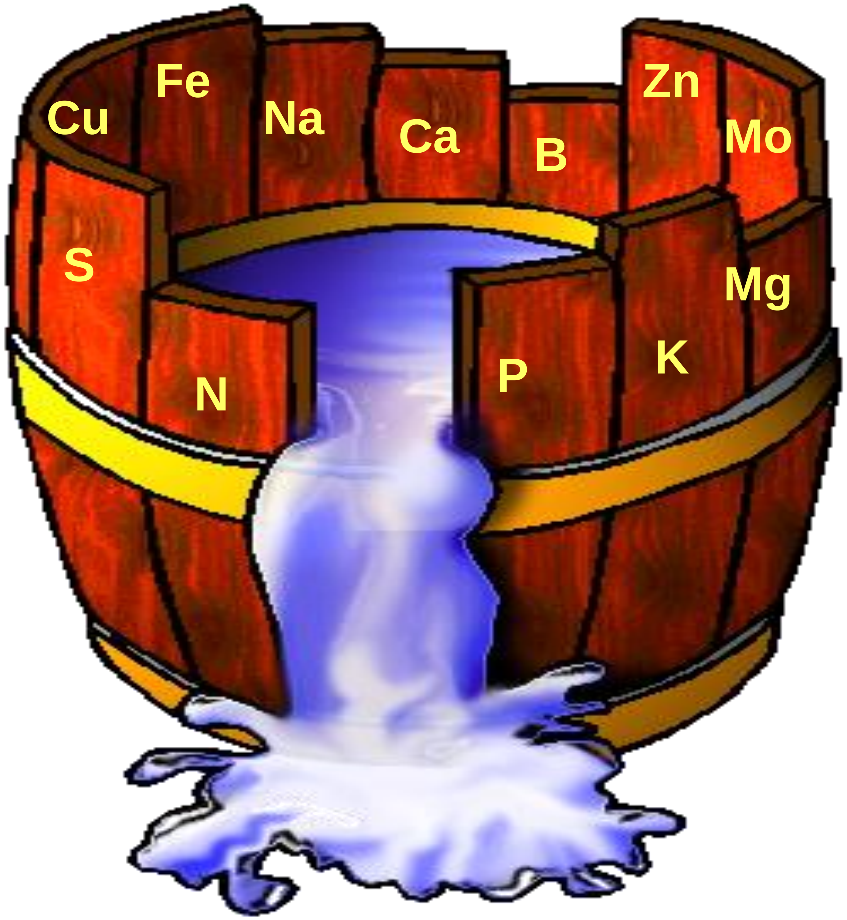




Soil Nutrition

Nutrients Balance

The law of least



Nutrient removal with 1 t/ha dry cocoa bean (incl. husks equivalent to 1 t of bean)

	Beans kg nutrient					Husks kg nutrient					Total kg nutrient				
	N	P_2O_5	K_2O	MgO	CaO	N	P_2O_5	K_2O	MgO	CaO	N	P_2O_5	K_2O	MgO	CaO
Cameroon	19,2	10,1	12,8	5,3	1,3	15,0	4,4	74,7	6,0	10,2	34,2	14,5	87,5	11,3	11,5
Ivory Coast	22,1	6,8	9,0	2,3	0,6	13,2	4,2	51,9	9,3	4,2	35,3	11,0	60,9	11,6	4,8
Nigeria	22,7	9,2	10,1			17,0	5,3	93,0			39,7	14,5	103,1		
Malaysia	20,4	8,2	12,6	4,5	1,5	10,6	3,0	52,2	4,1	5,3	31,0	11,2	64,8	8,6	6,8
SE Asia	20,0	4,7	11,3	2,7	1,3										
Philippines	21,3	9,2	11,4	5,0	1,4	14,5	4,1	75,6	5,0	7,8	35,8	13,3	87,0	10,0	9,2
Costa Rica	21,3	9,6	12,7			14,8	4,1	32,8			36,1	13,7	45,5		
Costa Rica	19,3	10,5	13,1			11,5	4,1	41,6			30,8	14,6	54,7		
Brazil	22,0					12,0					34,0				
Australia (QL)	22,8	10,9	8,3	5,6	1,5	21,9	7,7	30,3	7,9	10,5	44,7	18,6	38,6	13,5	12,0
Average	21,1	8,8	11,3	4,2	1,3	14,5	4,6	56,5	6,5	7,6	35,7	13,9	67,8	11,0	8,9

Ref: Boyer (1973), Lotode and Jadin (1981), Omotoso (1975), Thang and Ng (1978), Magat and Secretaria (2007), Heuveldop et al. (1988), Santana et al. (1982); Diczbalis et al. (2010)

Average nutrient requirements of Cacao
(kg/ha, based on 1075 trees/ha)

Stages of development	Crop age (Month)	N	P	K	Ca	Mg	Mn	Zn
Seedling (nursery)	5-12	2.4	0.6	2.4	2.3	1.1	0.04	0.01
Immature	28	128	13.6	114	151	113	3.9	0.5
1st year of production	39	212	23	321	140	71	7.1	0.9
Mature crop	50-87	438	48	633	373	129	6.1	1.5

Source: Panduan budaya Kakao

Nutrient uptake – whole plant

Mature Cacao plantation, 7 years old, 1100 trees/ha

	N	P_2O_5	K_2O	CaO	MgO	Mn	Zn
Average nutrient requirement (whole plant) kg/ha	453	114	788	540	221	7	1.6

Source: Modified after Thong & Ng (1978)

The (possible) role of Nutrition in Cocoa

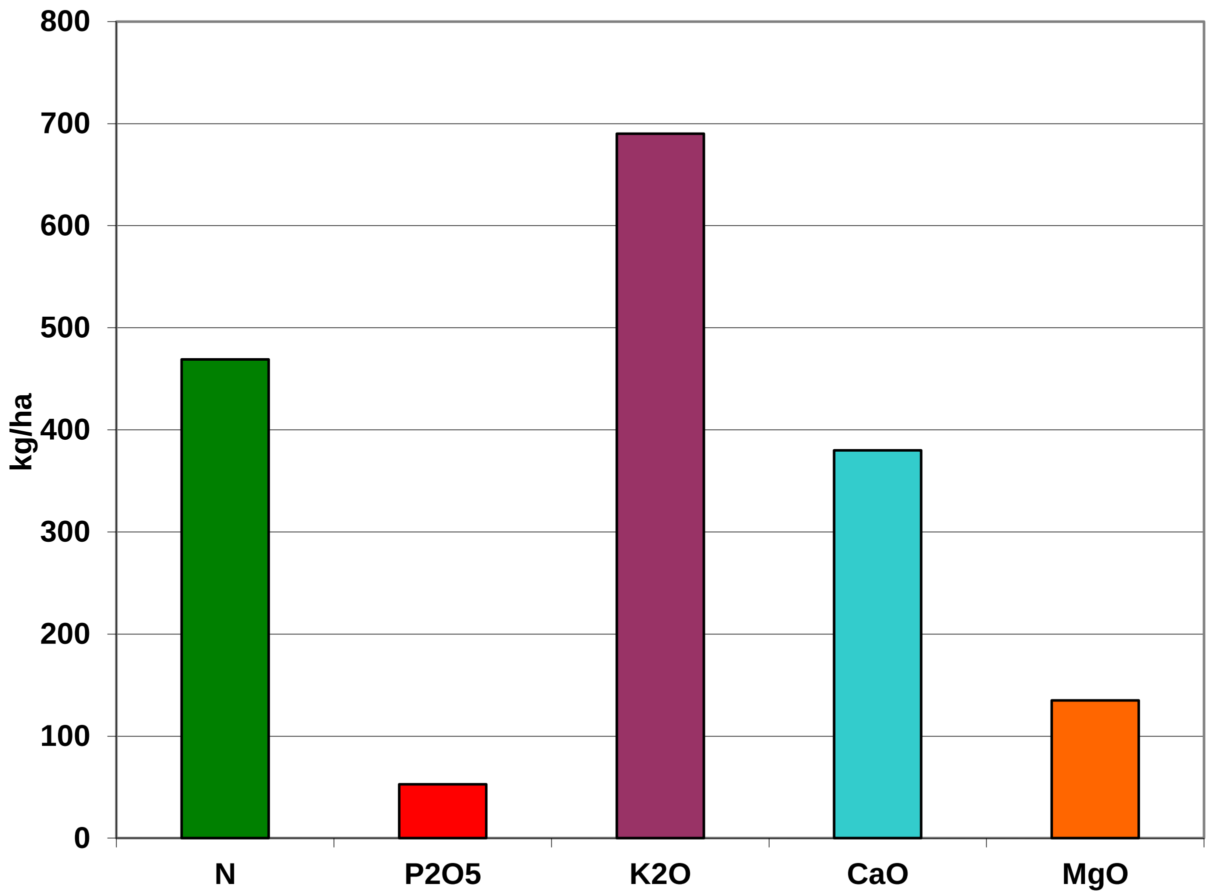
- adopted from Coffee Plantmaster

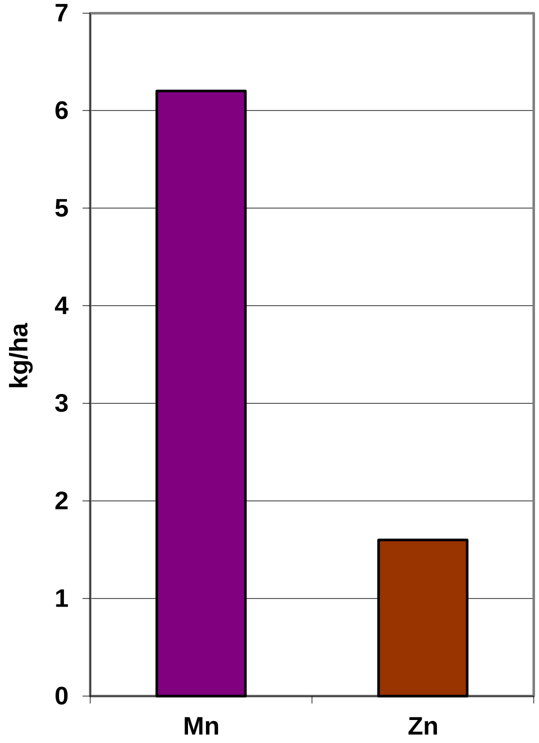
	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Mo	Zn
FLOWERING AND BERRY SET	Λ	Λ		Λ			Λ					Λ
BEAN SIZE	Λ	Λ	Λ				Λ					Λ
YIELD	Λ	Λ	Λ	Λ	Λ	Λ	Λ	Λ	Λ	Λ		Λ
DISEASES	Λ		V	V		V	V	V		V		V
CAFFEINE CONTENT					Λ	Λ						

INCREASE Λ REDUCTION V

Adapted from Coffee Plantmaster

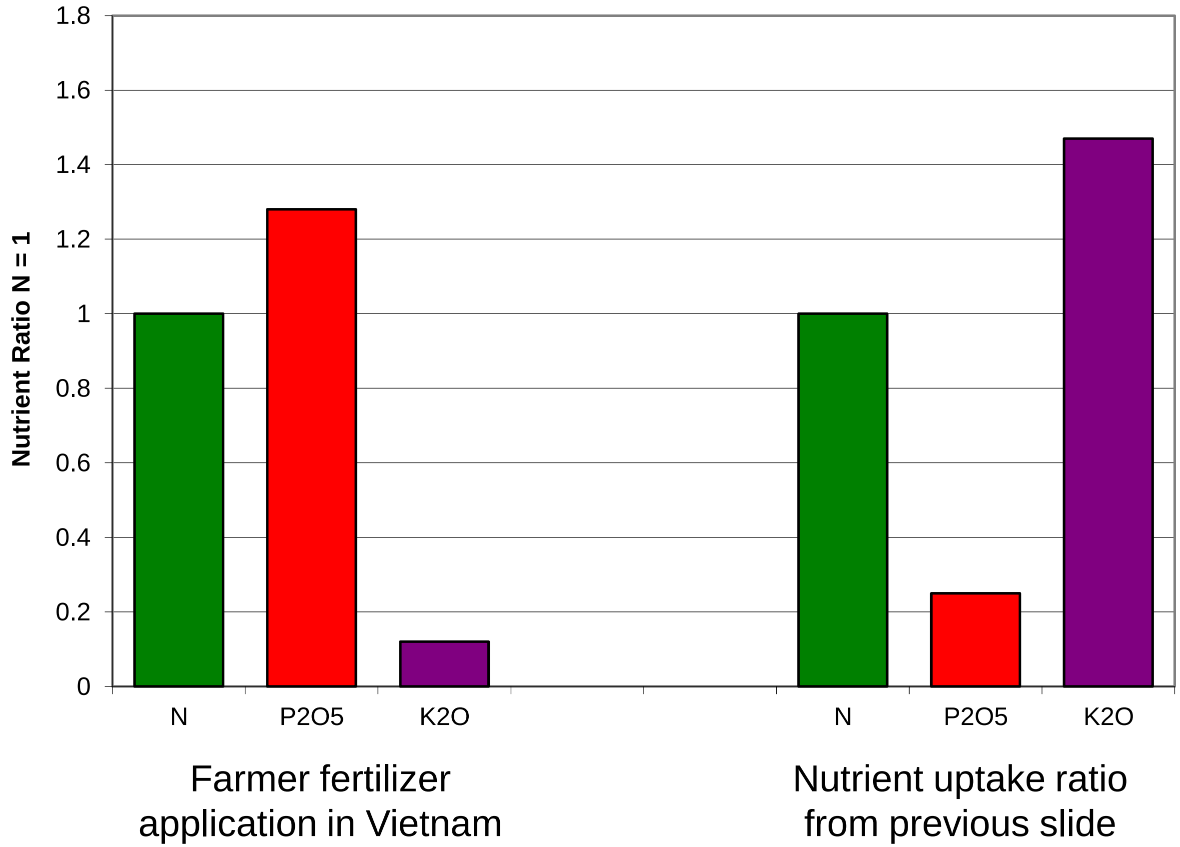
Nutrient demand (uptake & removal)
1000kg/ha/year dried beans - Malaysia





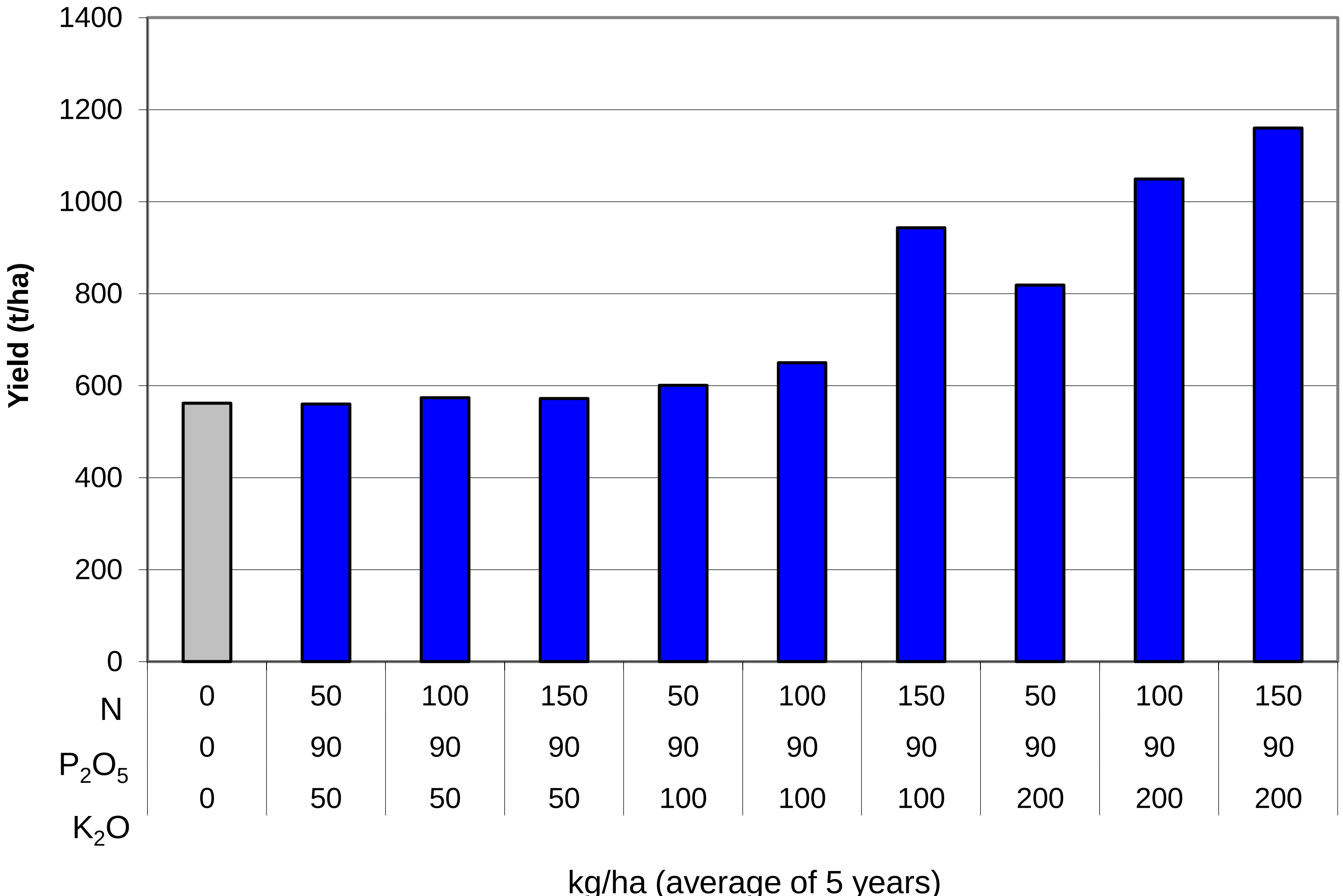
Nutrient balance is important

Seeds in pod from low K application fail to fill completely



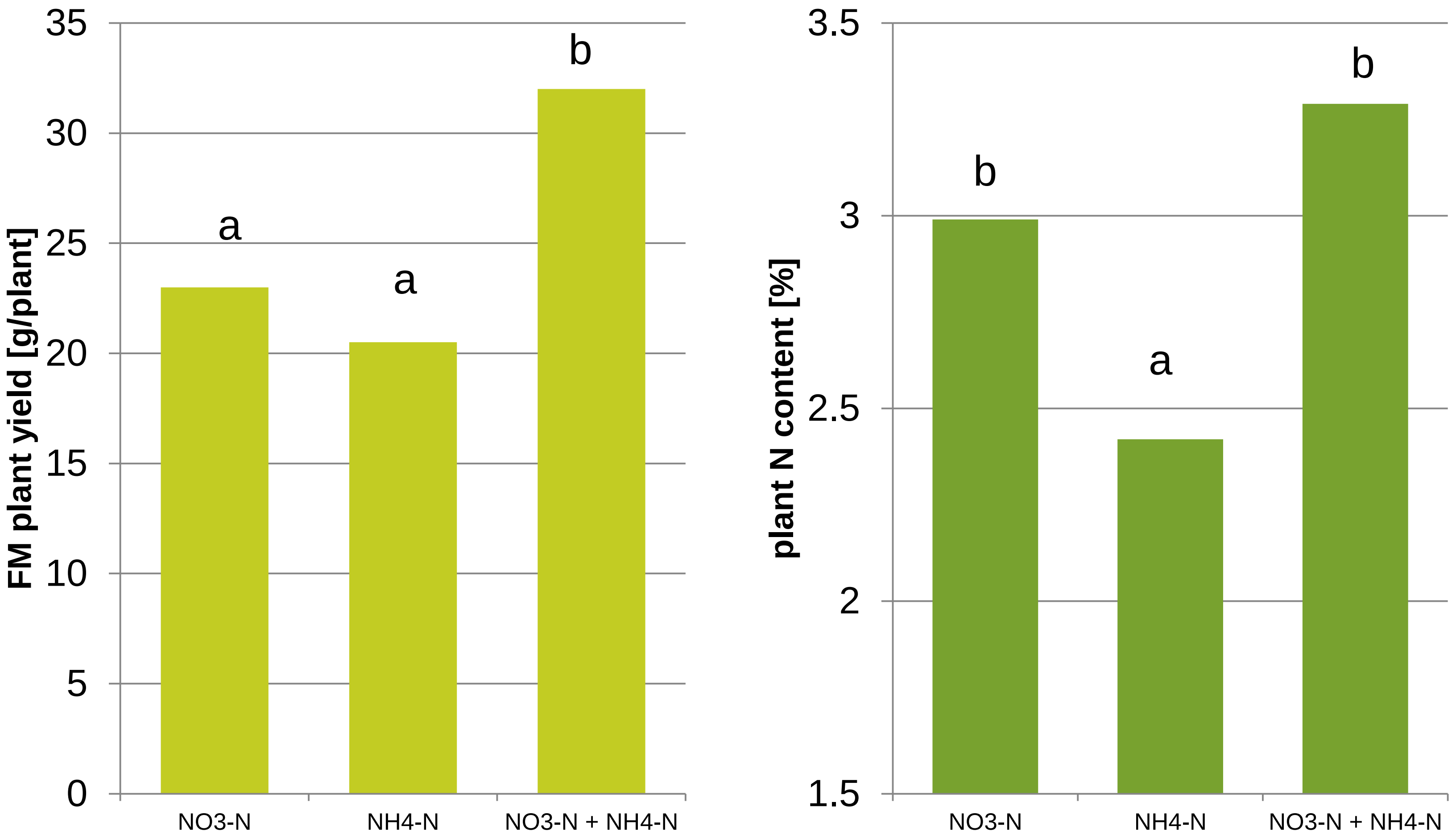
Balanced Nutrition is important

Colombia-Cacao



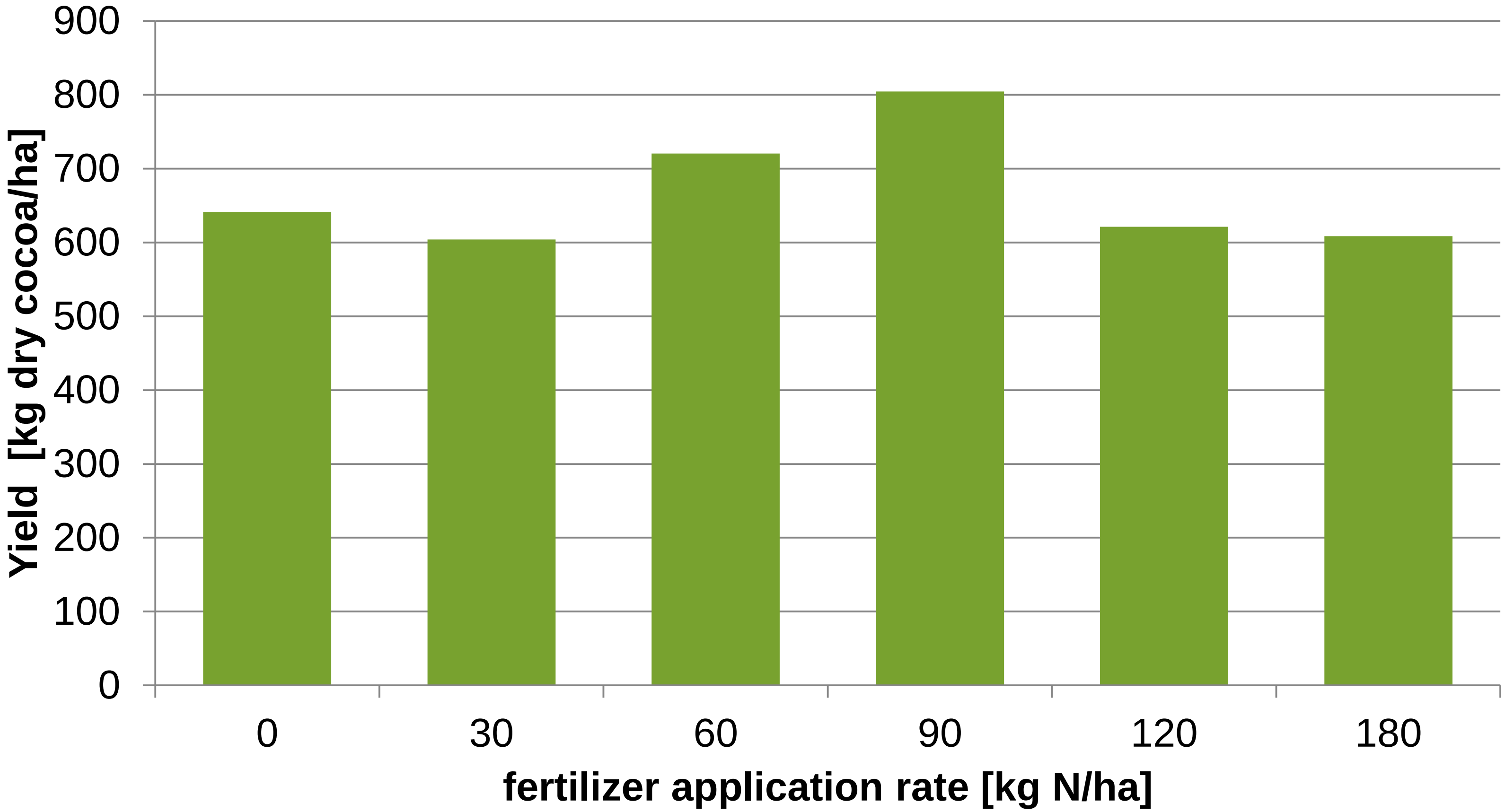
Ref. Uribe et al. (1998)

Impact of different N forms on growth and N uptake of cocoa seedlings - Brazil



source: Santana, 1980

Impact of different nitrogen rates on cocoa yield
- Ghana. 3-year avg.

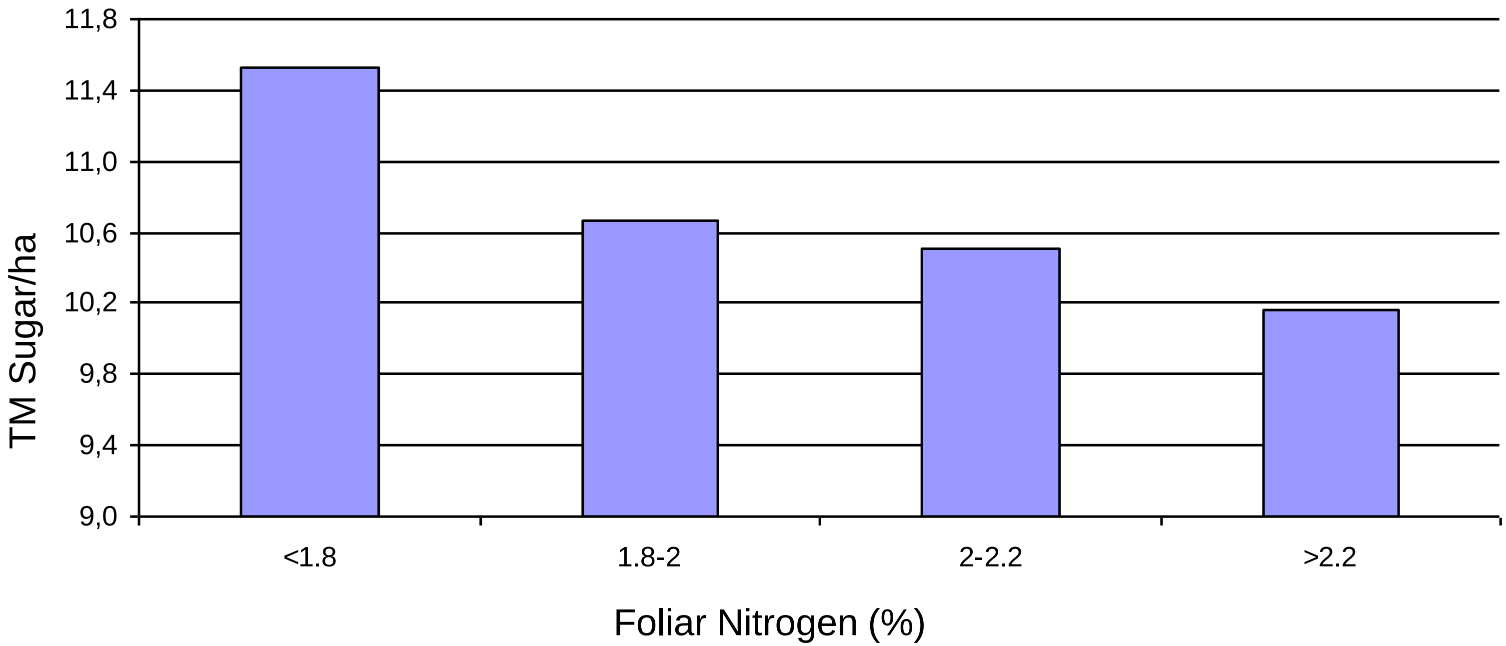


N application of 90 kg N/ha resulted in highest yield.
No further yield increase with increase in N rates, because of unbalanced nutrition (low K).

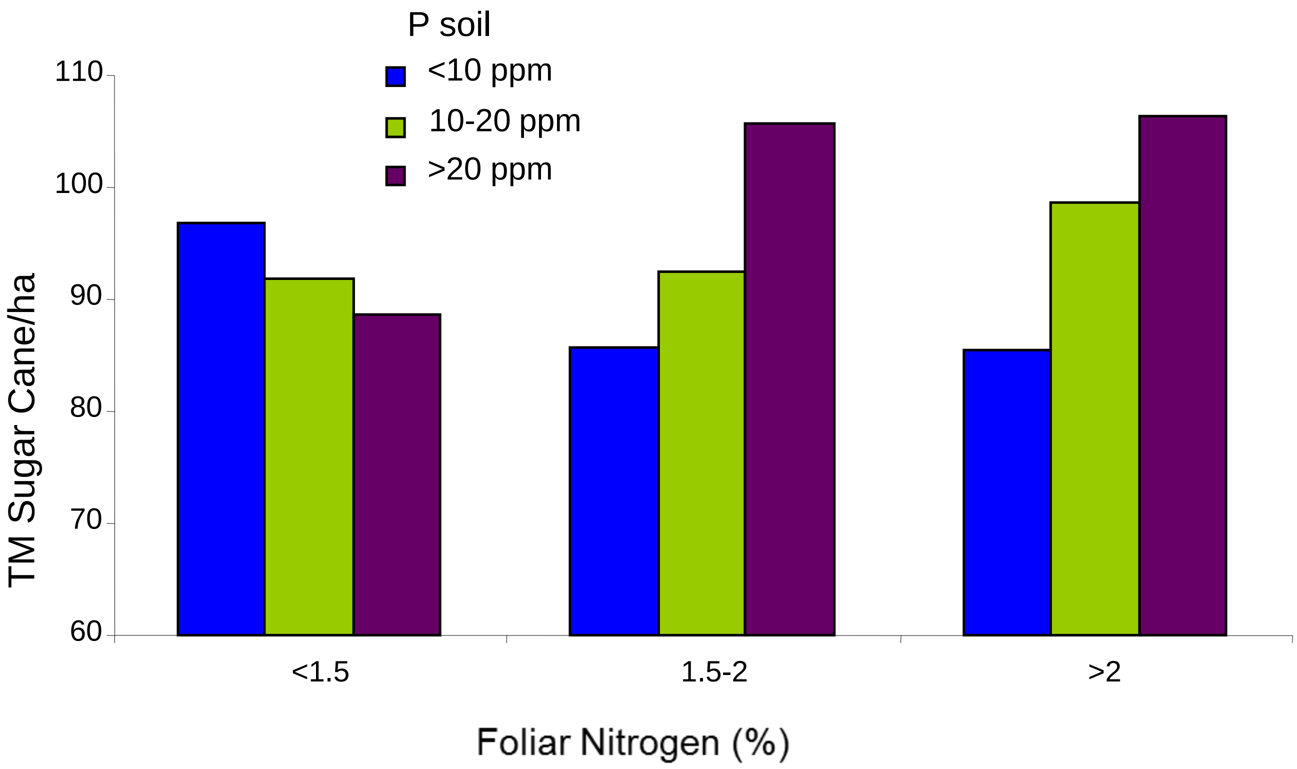
Base dressing with 115 kg P2O5 and 76.5 kg K2O/ha; N as ammonium sulphate

source: Ofori-Frimpong. 2003

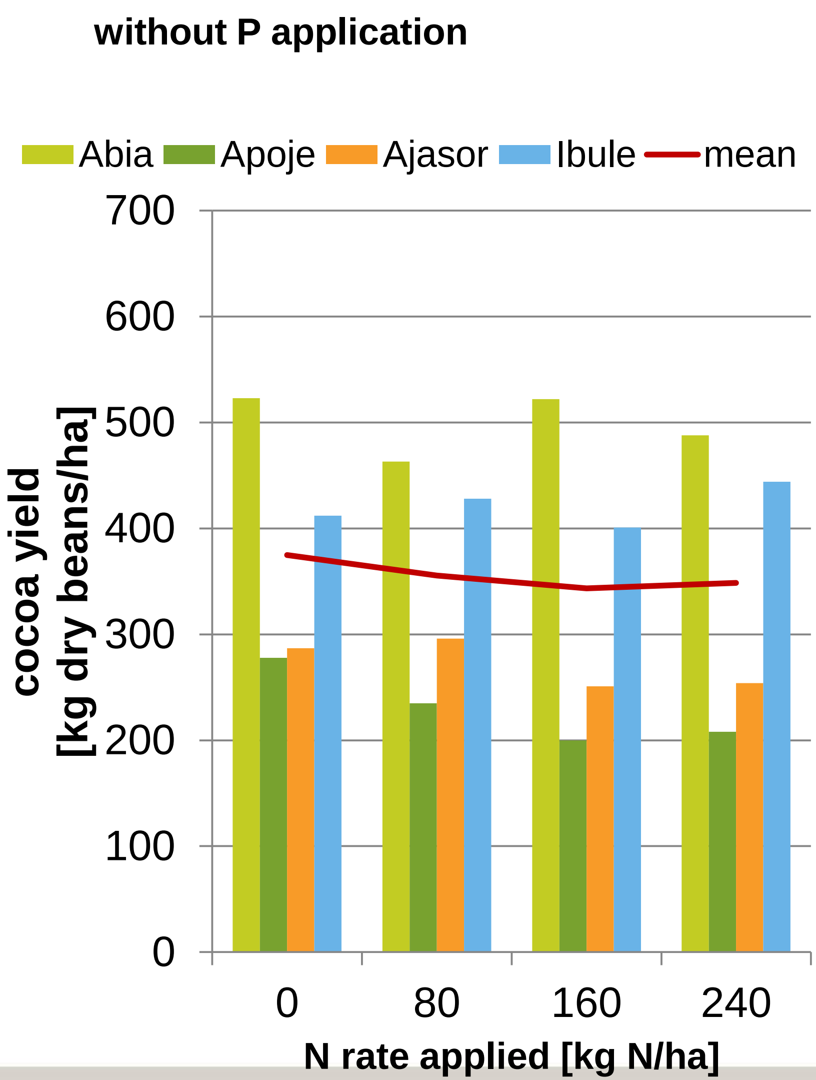
Relationship between the content of foliar Nitrogen and TM Sugar/ha

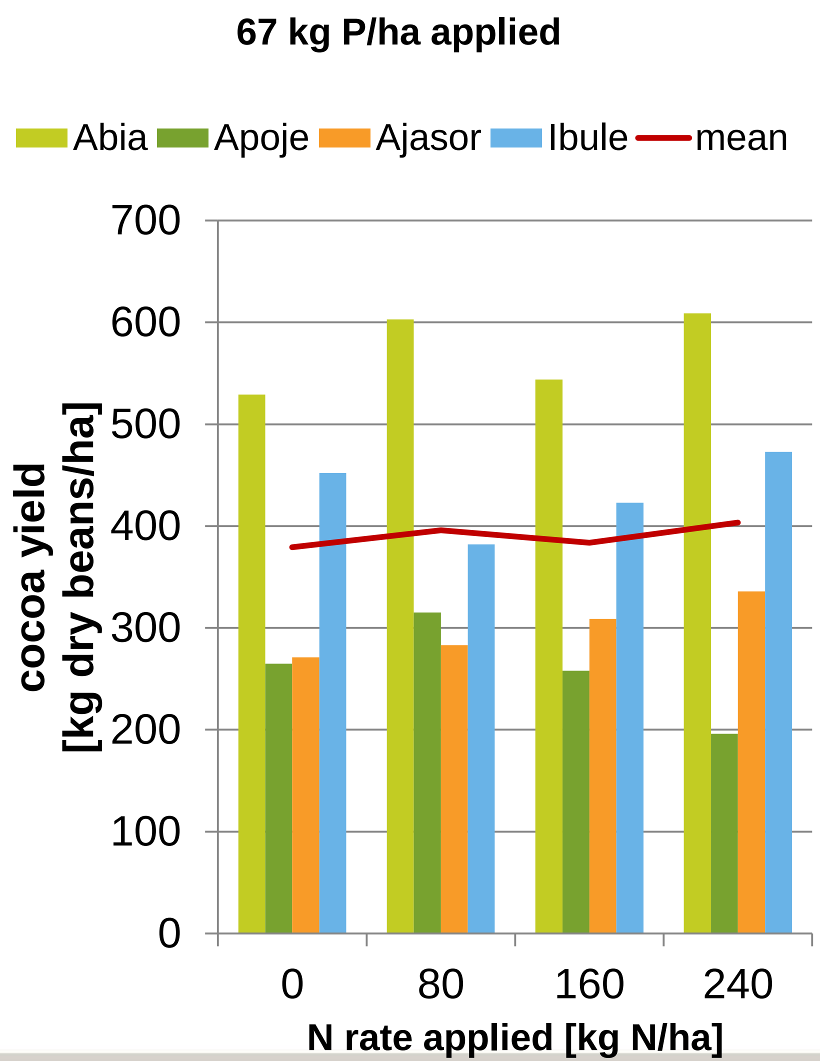


Foliar Nitrogen and Sugar Cane Yield, according to the phosphorus level in the soil

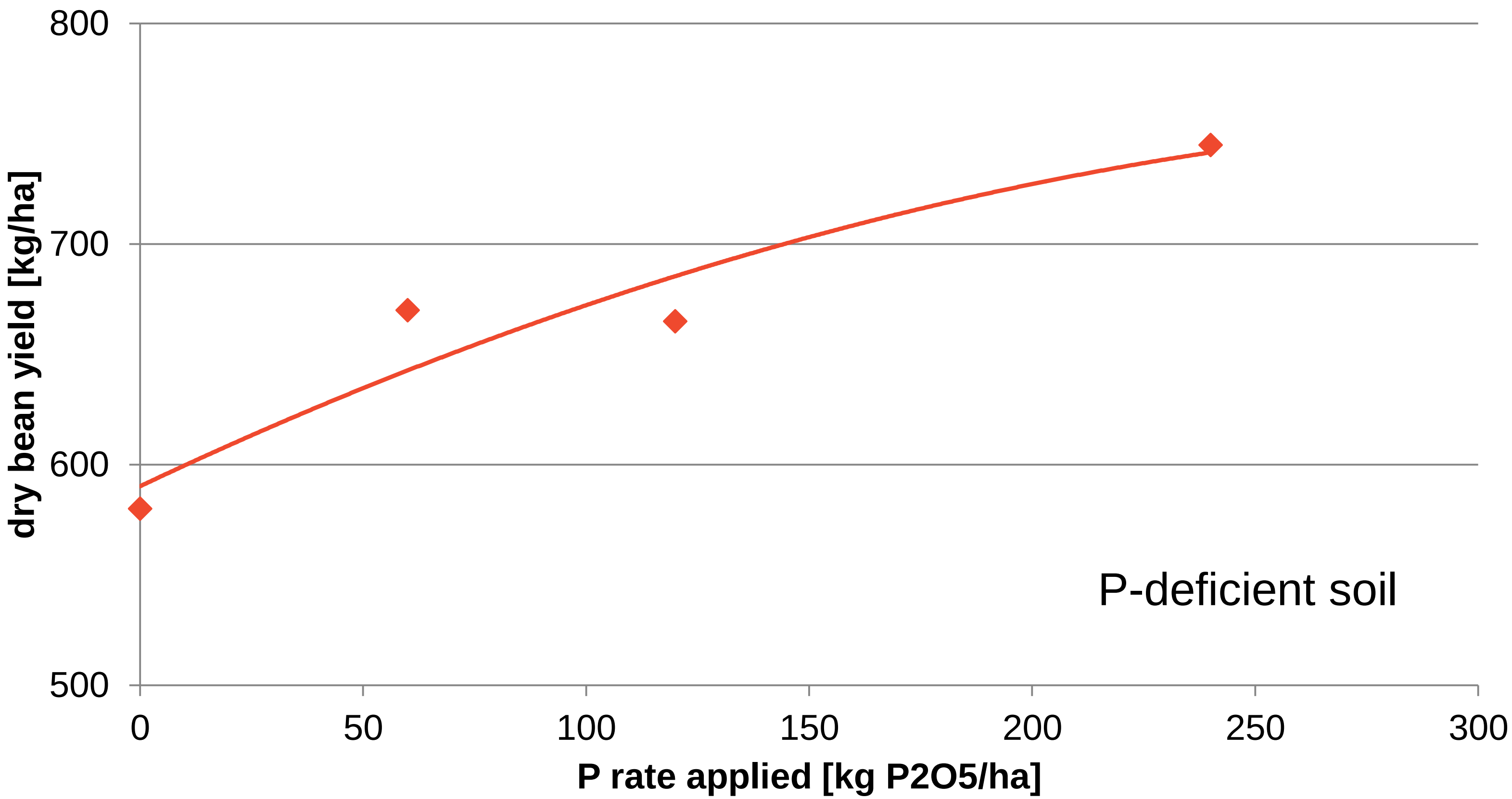


Phosphorus application increases cocoa yield in the presence of nitrogen - Nigeria





Impact of increasing phosphorus rates on bean yield of cocoa - Brazil



P was applied as TSP, the initial soil P content is 1-3 mg P/kg soil

source: Morais 1998b

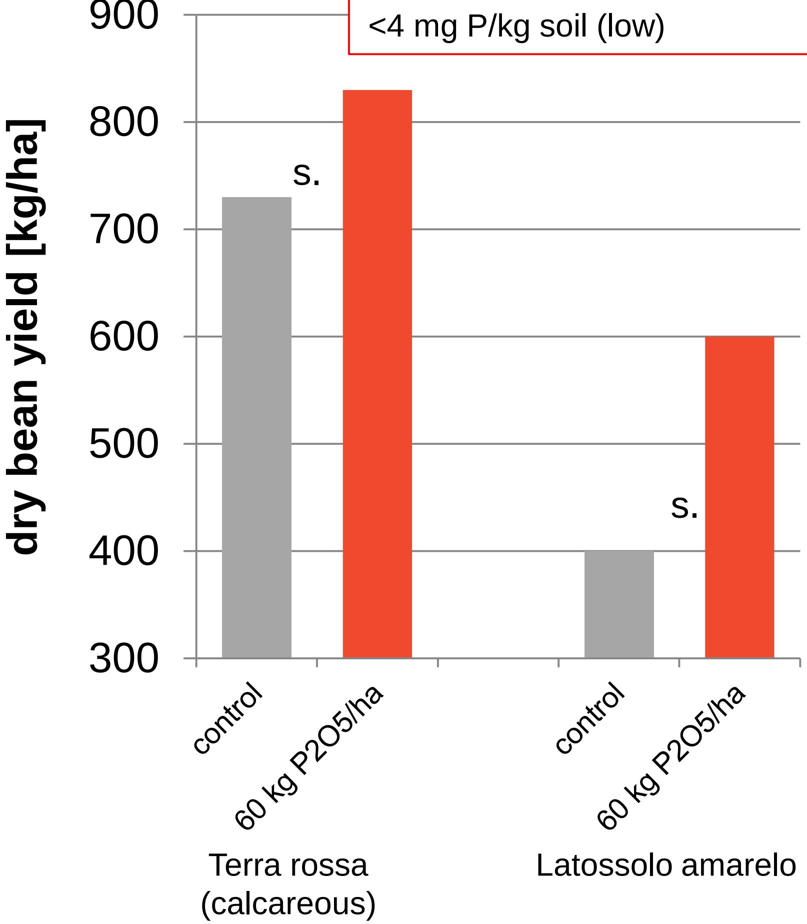
Impact of phosphorus application on yield and incidence of ‚witches broom‘ in cocoa - Brazil

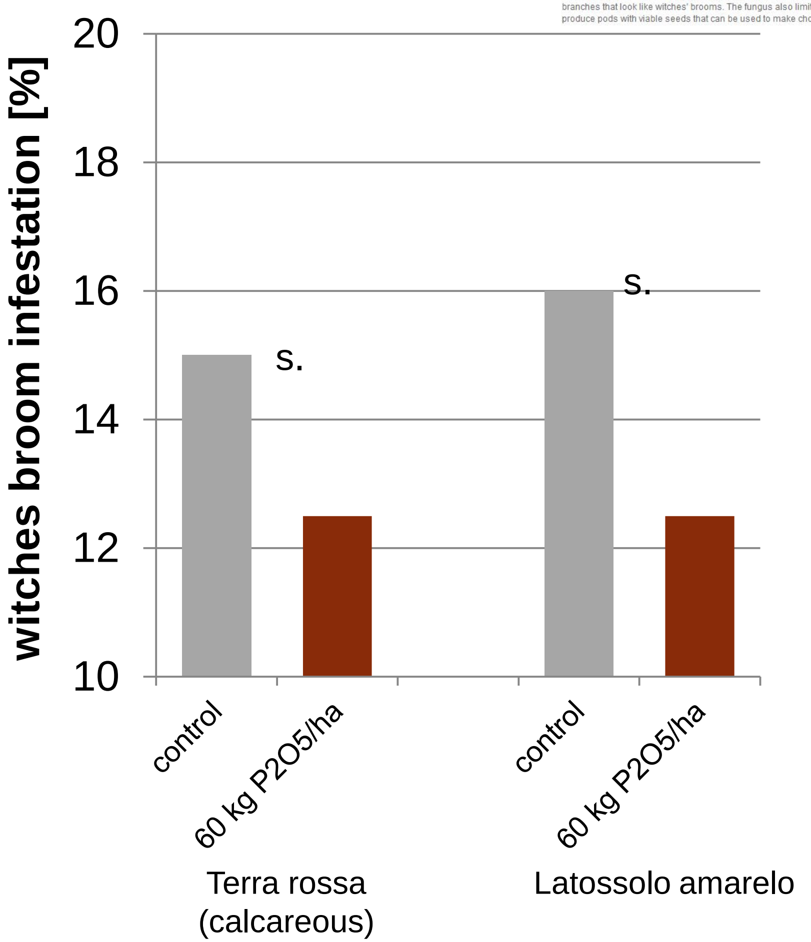
Anna Vigran/NPR

When the witches'-broom fungus infects cacao trees, they grow stunted clusters of branches that look like witches' brooms. The fungus also limits the trees' ability to produce pods with viable seeds that can be used to make chocolate.

oto source: http://www.dropdata.org/cocoa/icm_bkp.htm

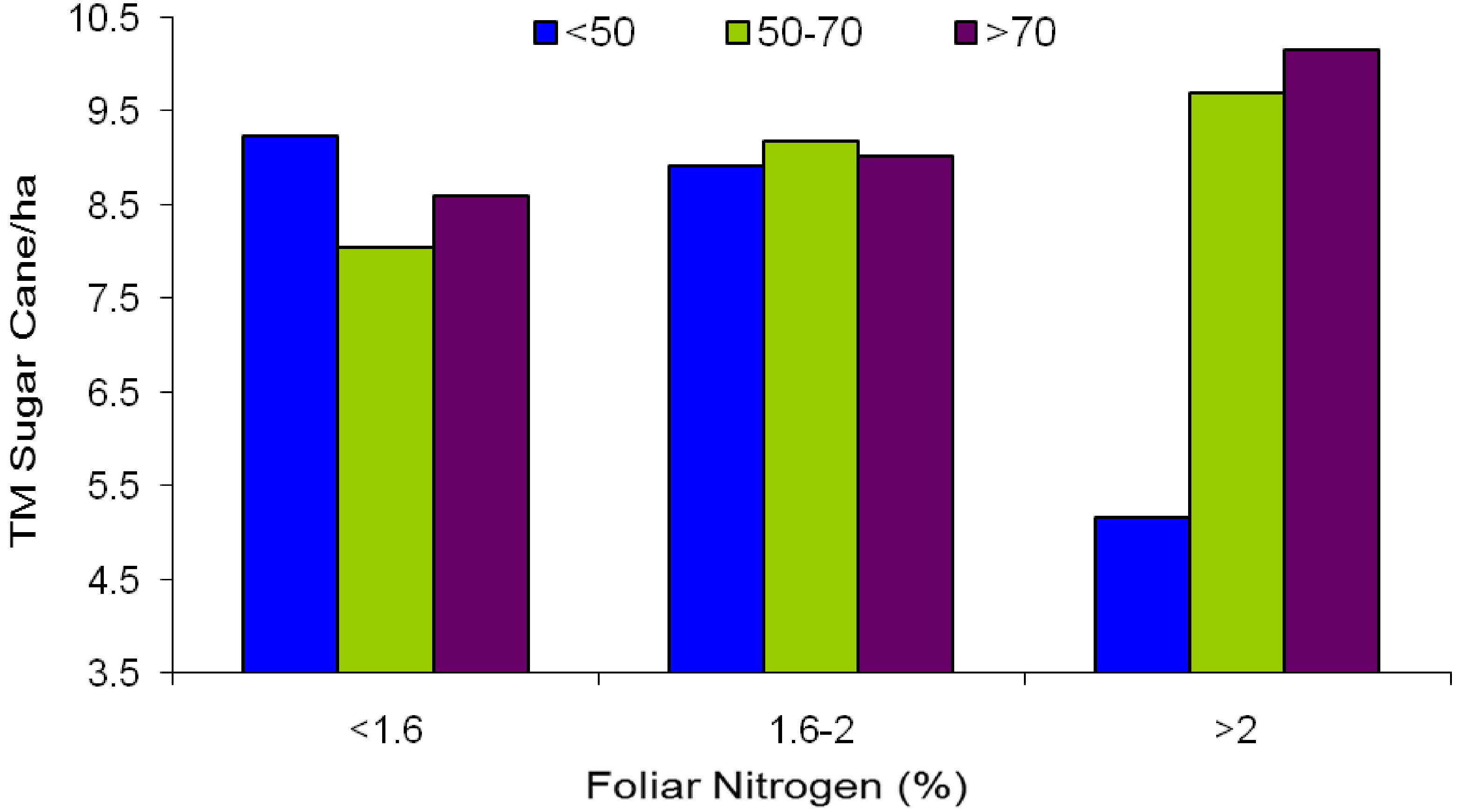
initial P content on both soils
<4 mg P/kg soil (low)



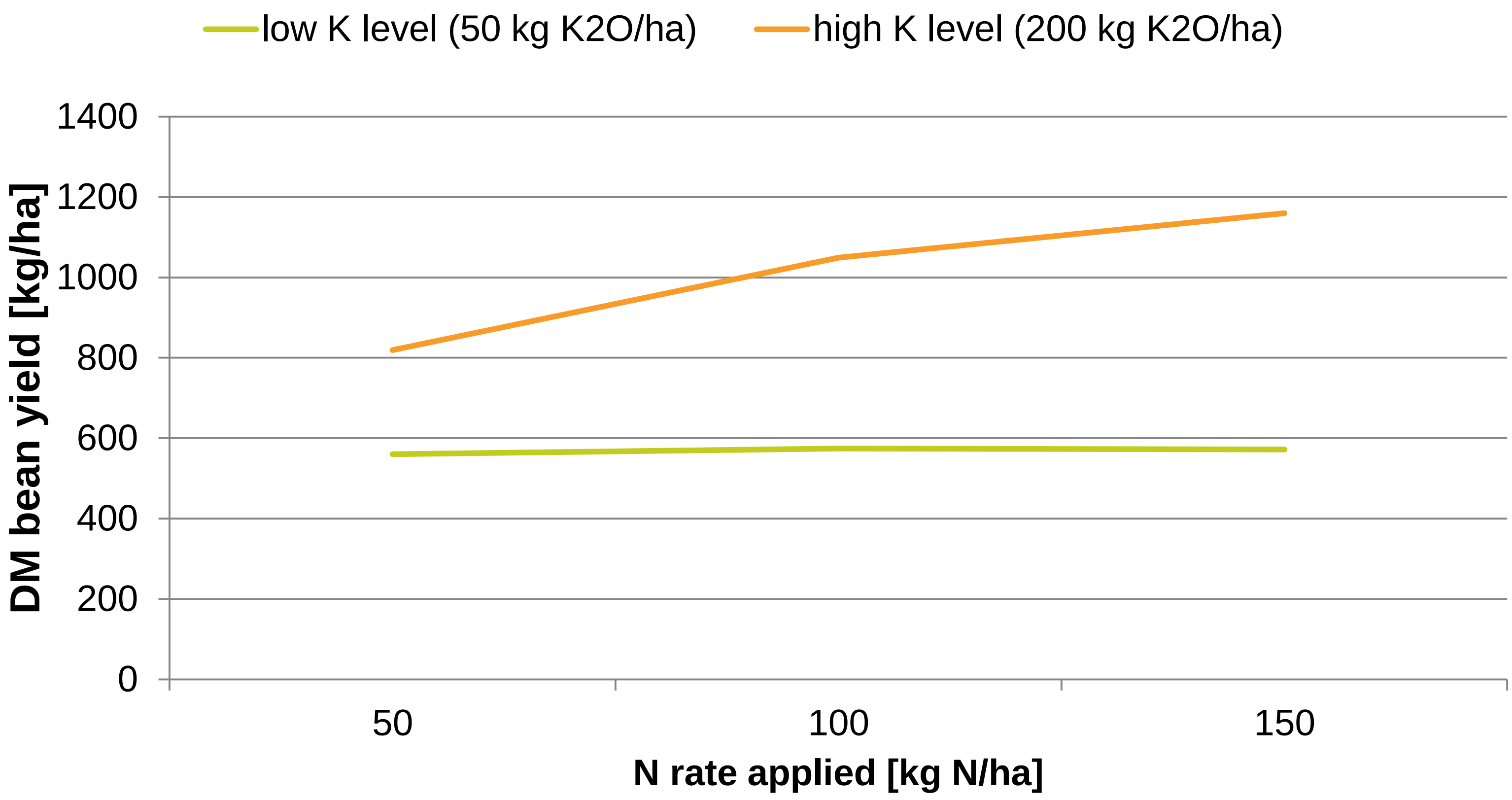


source: Morais 1998b

Foliar Nitrogen and Sugar Production, according to the Saturation Level of Foliar K

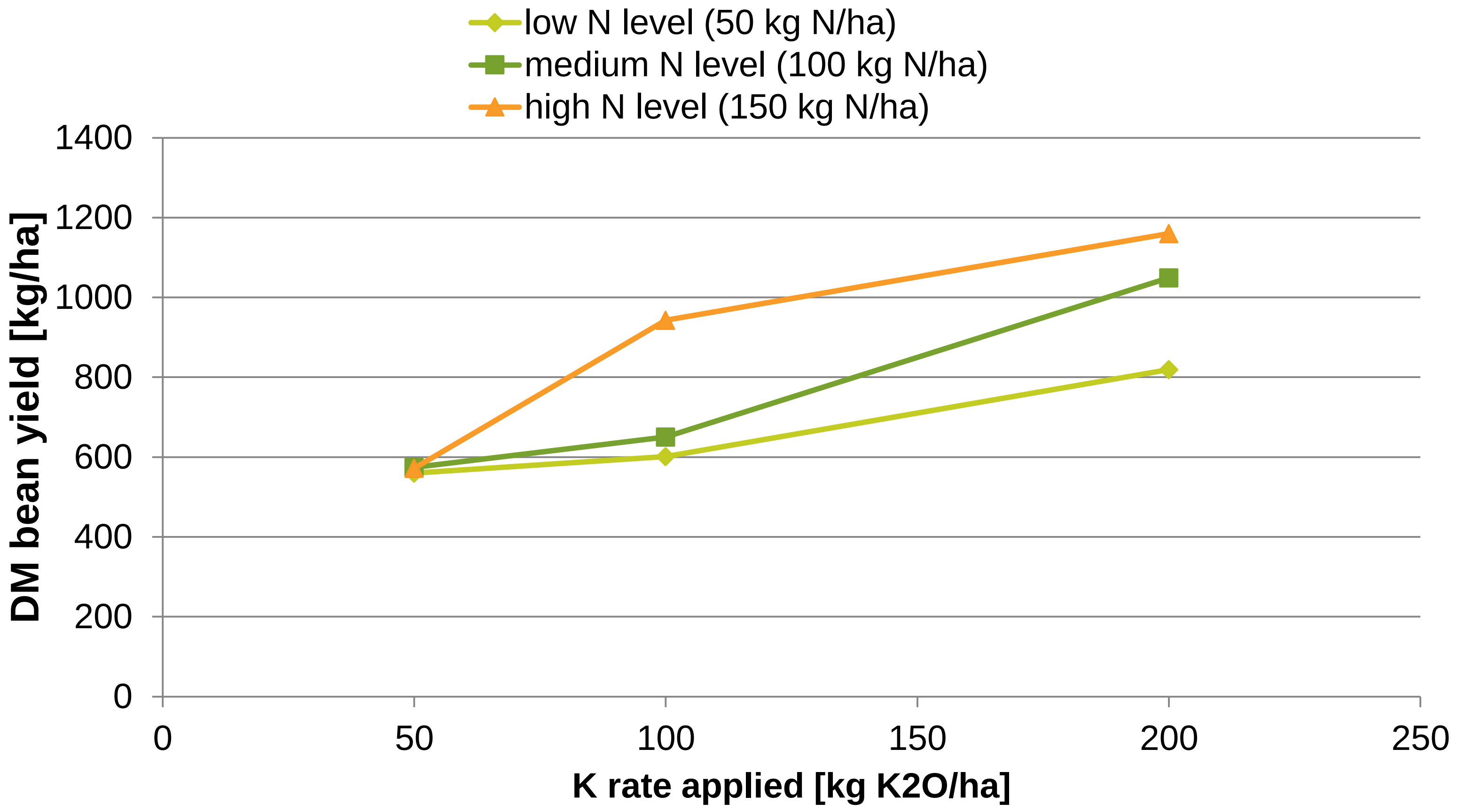


Impact of increasing nitrogen rates on cocoa yield - Colombia



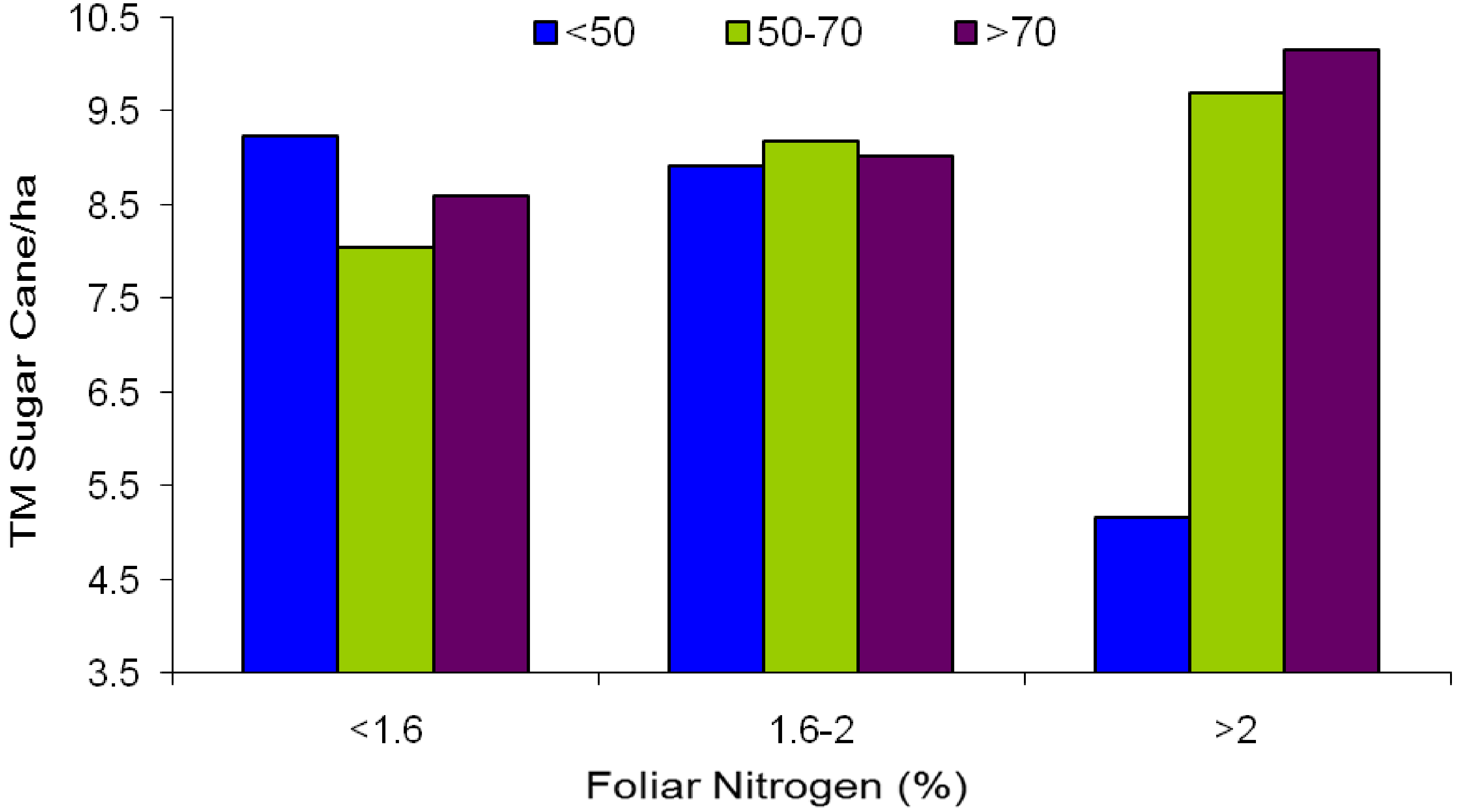
source: Uribe, 2000

Impact of increasing potassium rates on cocoa yield, Colombia

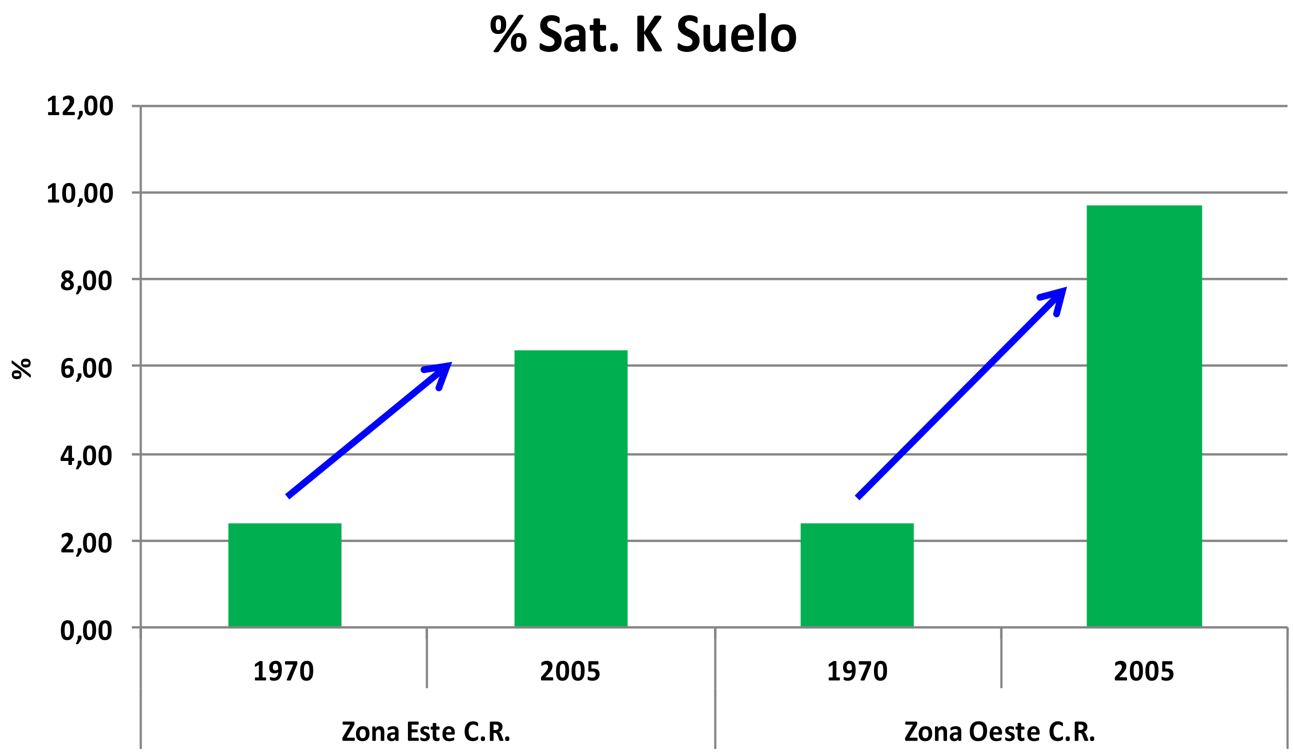


source: Uribe, 2000

Foliar Nitrogen and Sugar Production, according to the Saturation Level of Foliar K

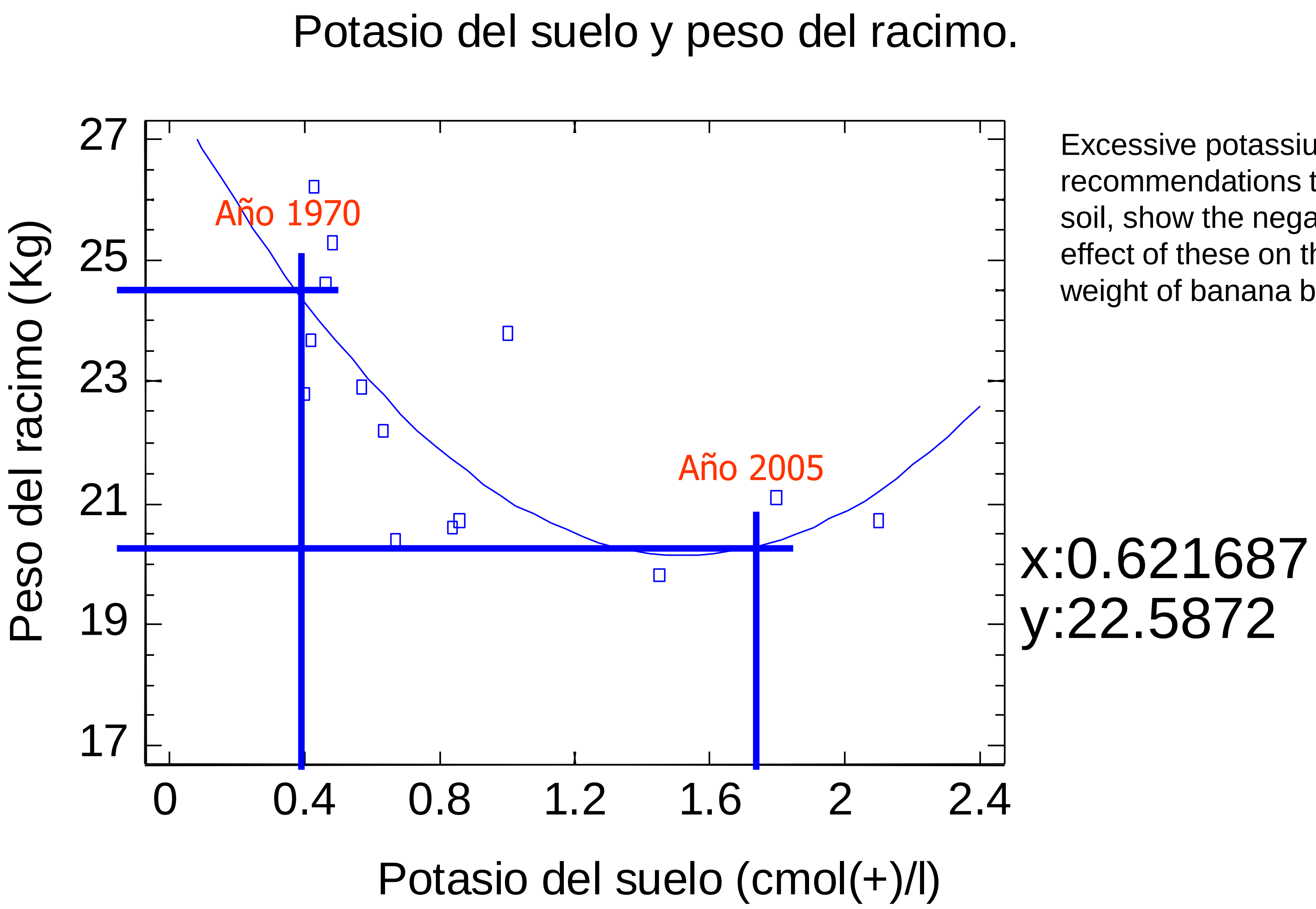


Evolution of Potassium Saturation in Soil



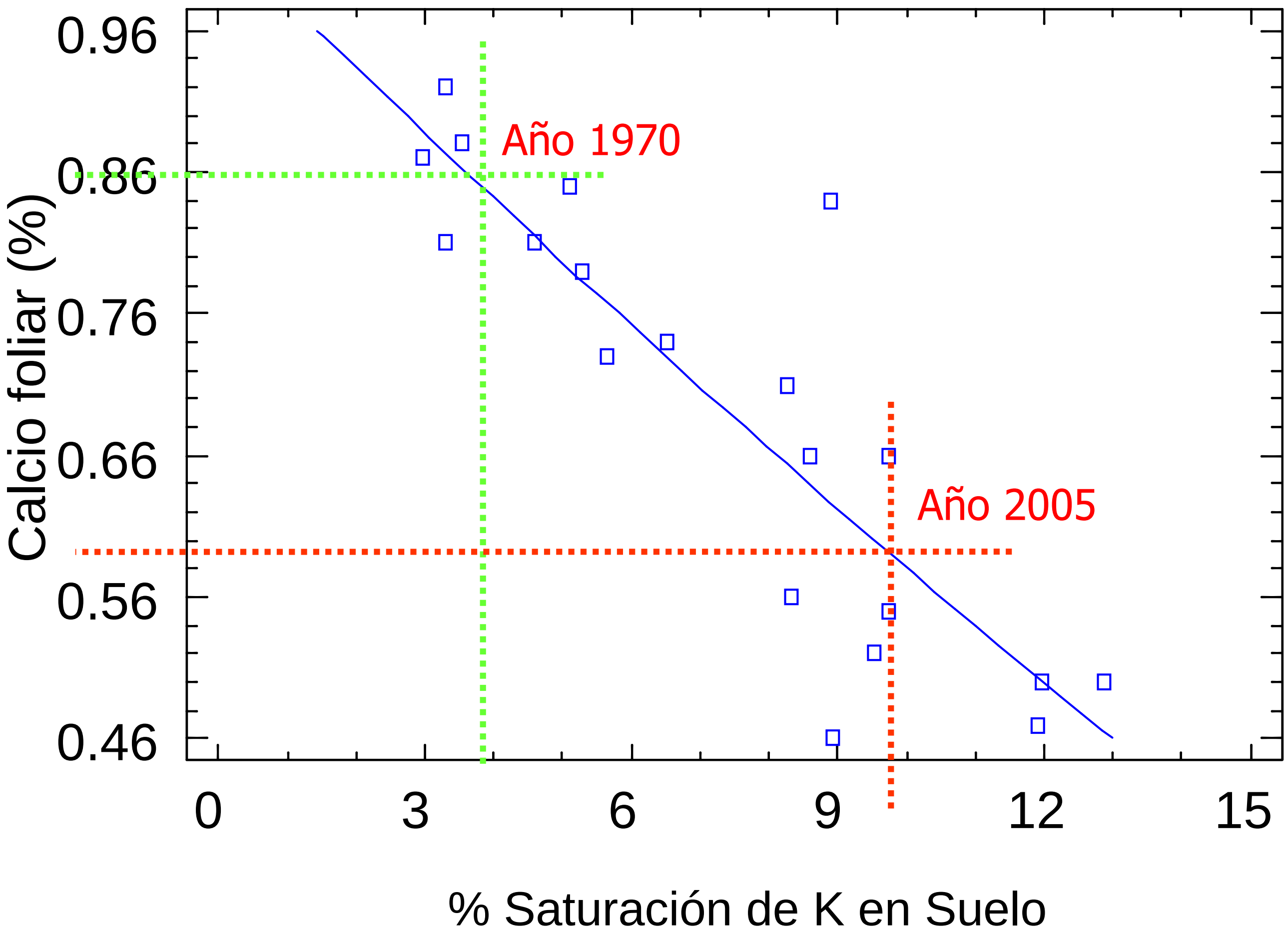
Excessive applications of potassium as KCl to achieve doses up to 1000 kg/ha/year, generated over time nutritional imbalances, mainly against Calcium. Old Nutrition did not consider the application of soluble calcium immediately available to the plant; It generated over time nutritional imbalances that favor the presence of metabolic disorders such as maturity bronzing. Currently Nitrabor including, allows the proper balance of bases on the soil and the leaf.

Bunch weight in time… !!!



Excessive potassium recommendations to the soil, show the negative effect of these on the weight of banana bunch.

Foliar Calcium and Potassium Saturation in Soil



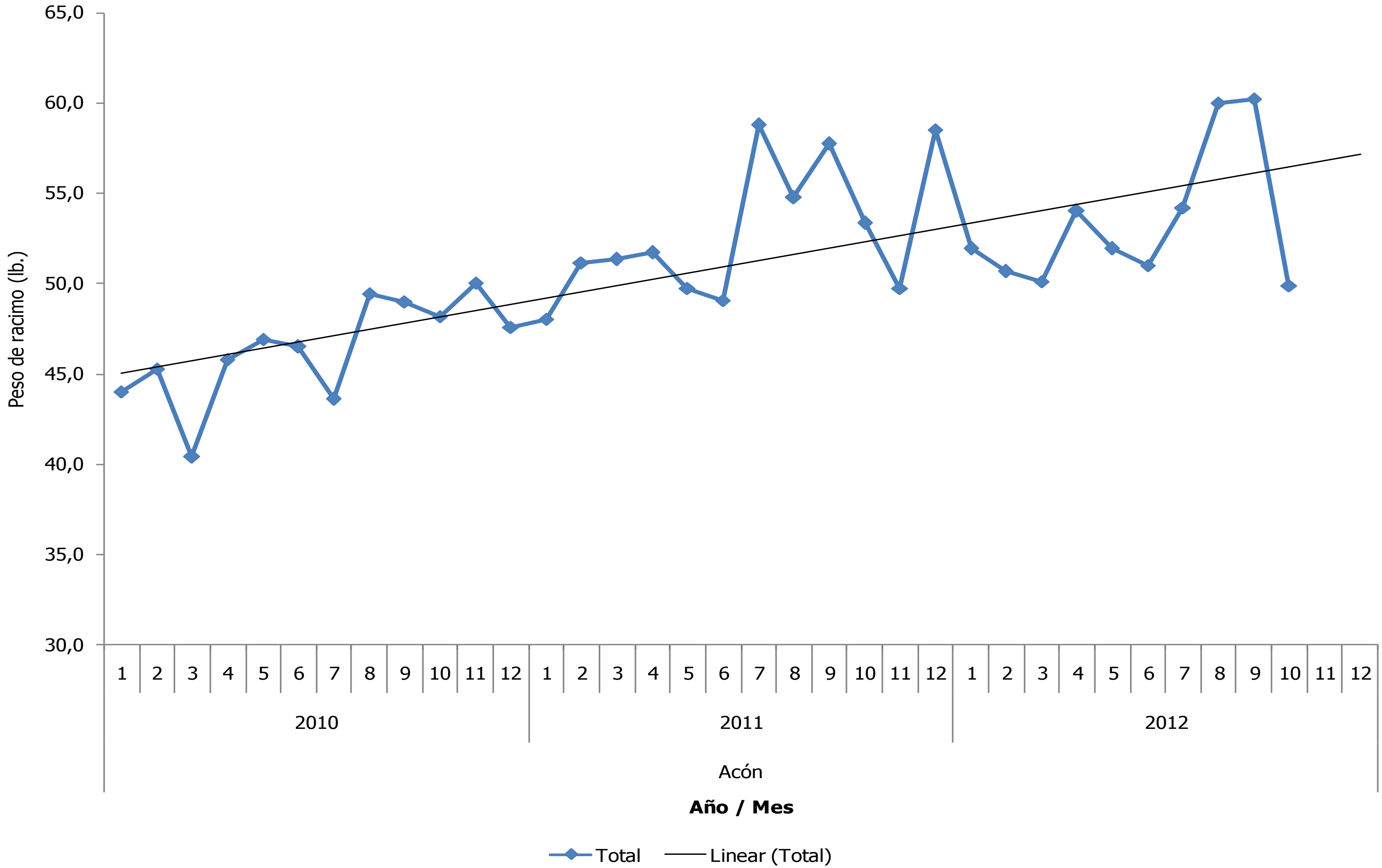
One of the main effects of excess potassium in the soil, is foliar Ca deficiency. At equilibrium soil bases, more potassium has absorbability than Ca and Mg.

x:4.02806
y:0.86378

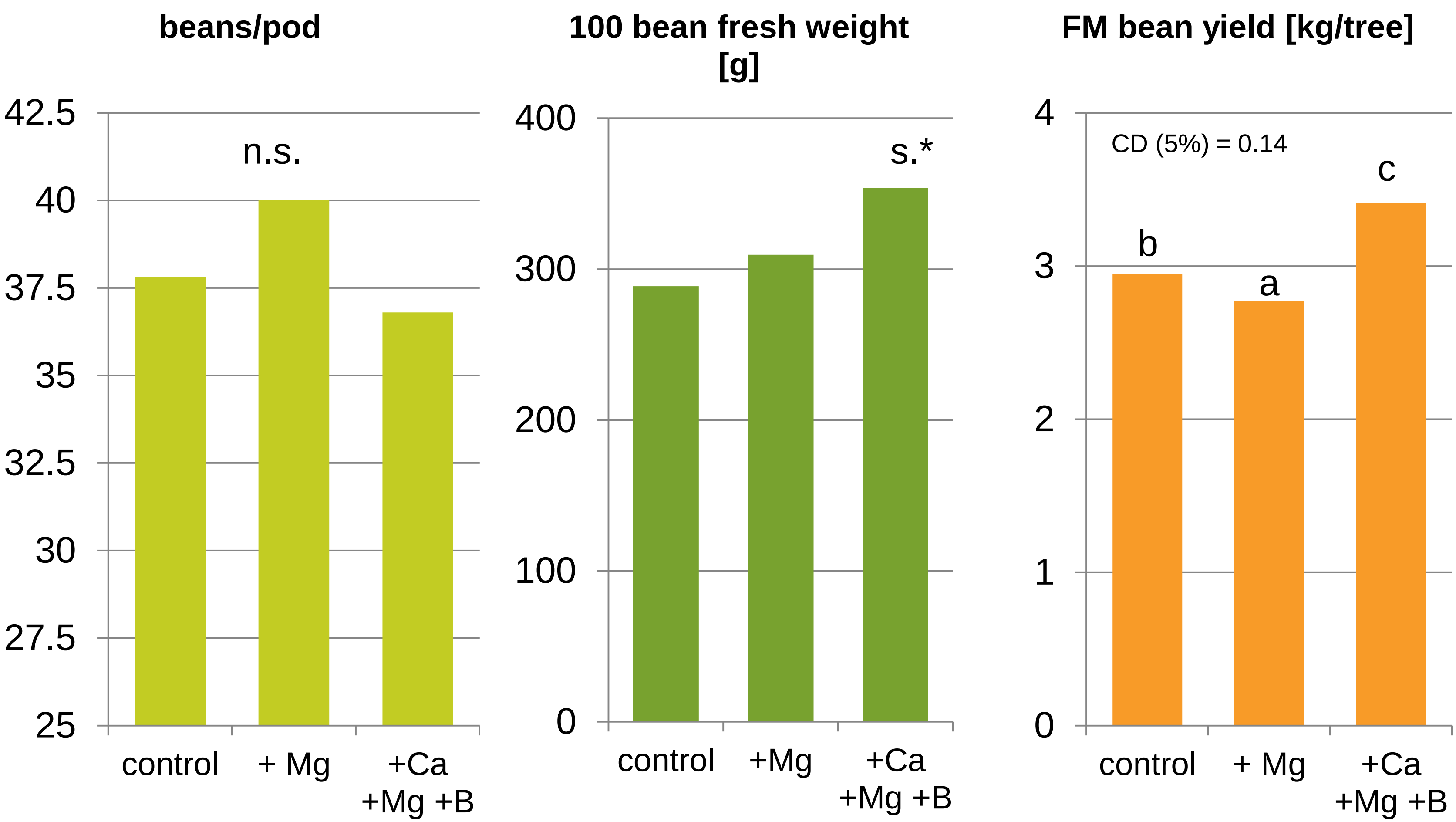
Evolution of the Soil Nutrition in banana

	kg/Ha/año					
	Nutriente	**1970**	**2000**	**2005**	**2010**	**2015**
kg/Ha/año	N	700	500	475	400	400-375
	P_2O_5	150	120	80	50	30-20
	K_2O	1000	700	450	400	400-500
	MgO	0	40	75	100	100-120
	B	0	12	8	5	5-3
	CaO	0	0	125	150	150-200
	S	200	100	100	120	120-80
	Zn	0	20	14	8	4-0

Bunch Weight



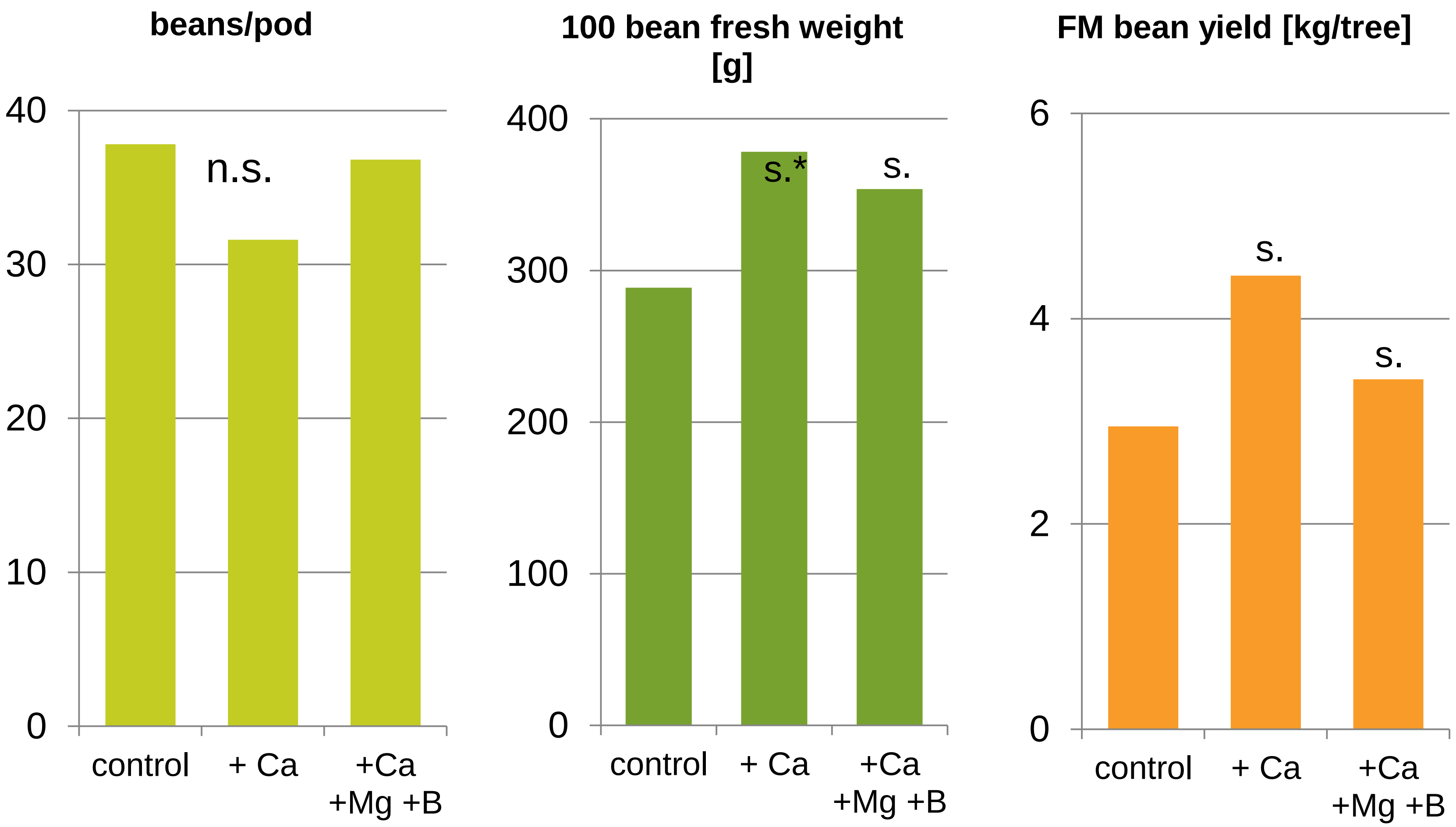
Effect of magnesium application on cocoa yield - India



* significant to control treatment

source: Uthaiah, 1980

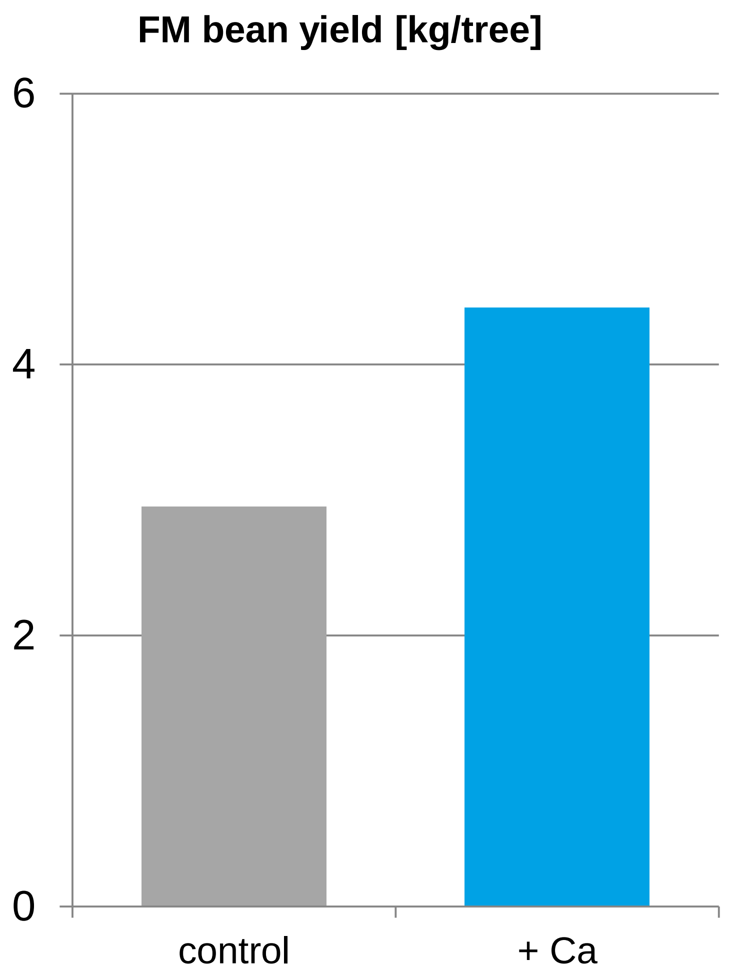
Effect of calcium application on cocoa yield and quality - India

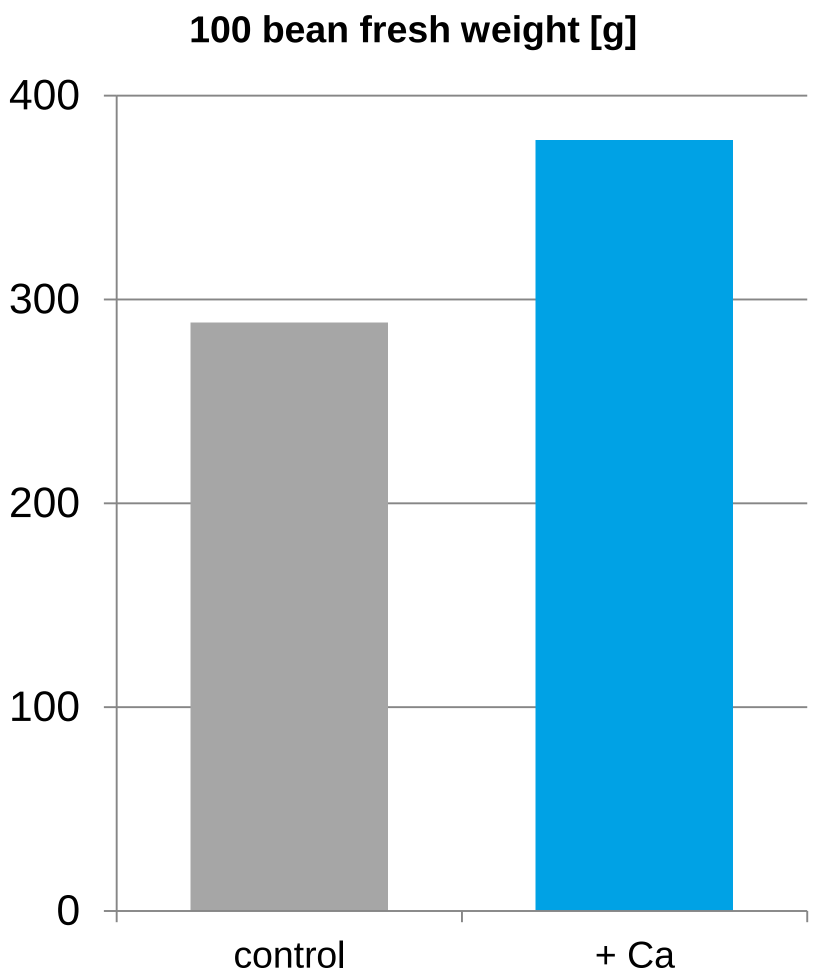


* significant to control treatment

source: Uthaiah, 1980

Calcium application improves yield and bean weight
- India

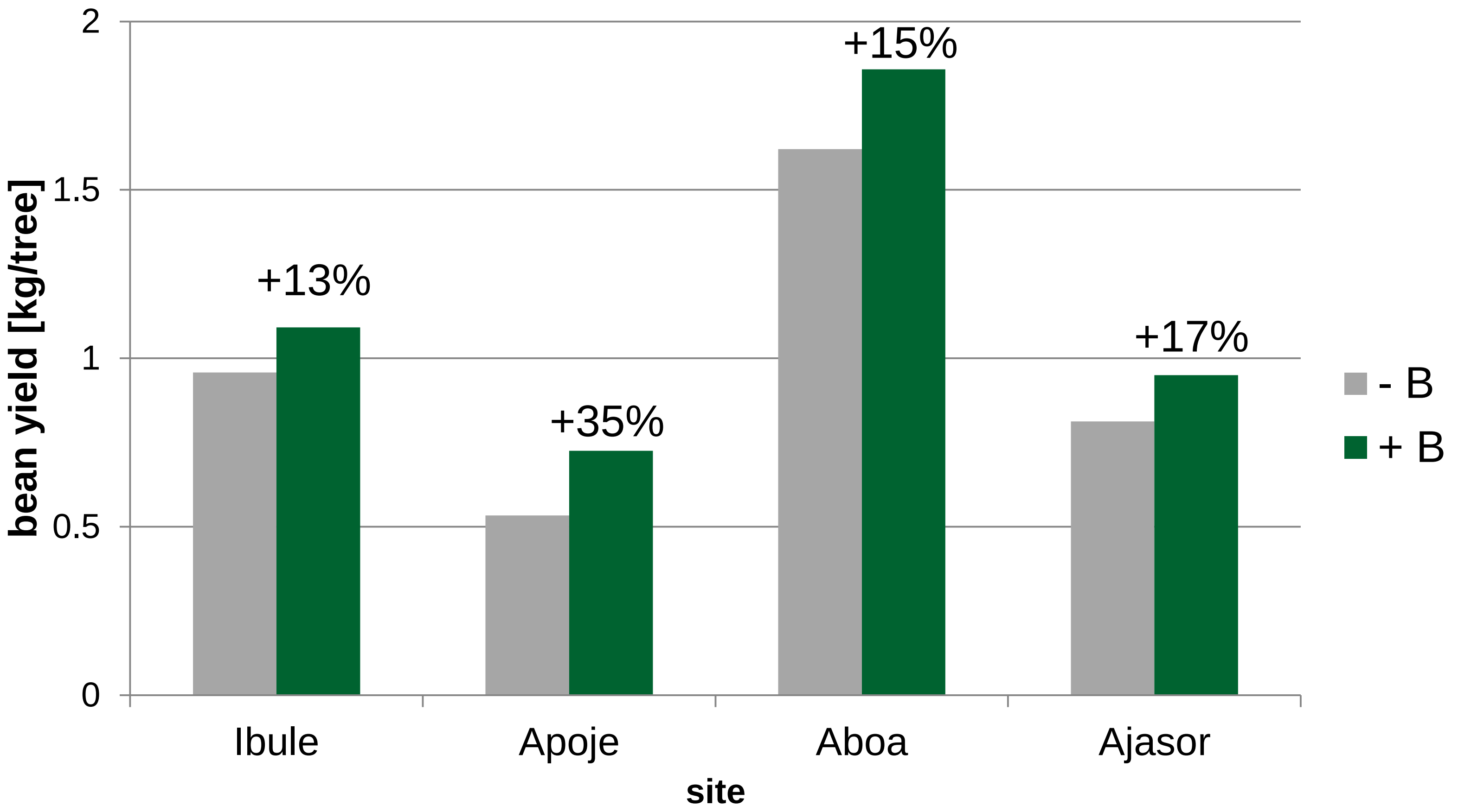




source: Uthaiah. 1980

Calcium: 10 g CaCl2/tree in 2 L water + 60 g CaCl2/tree

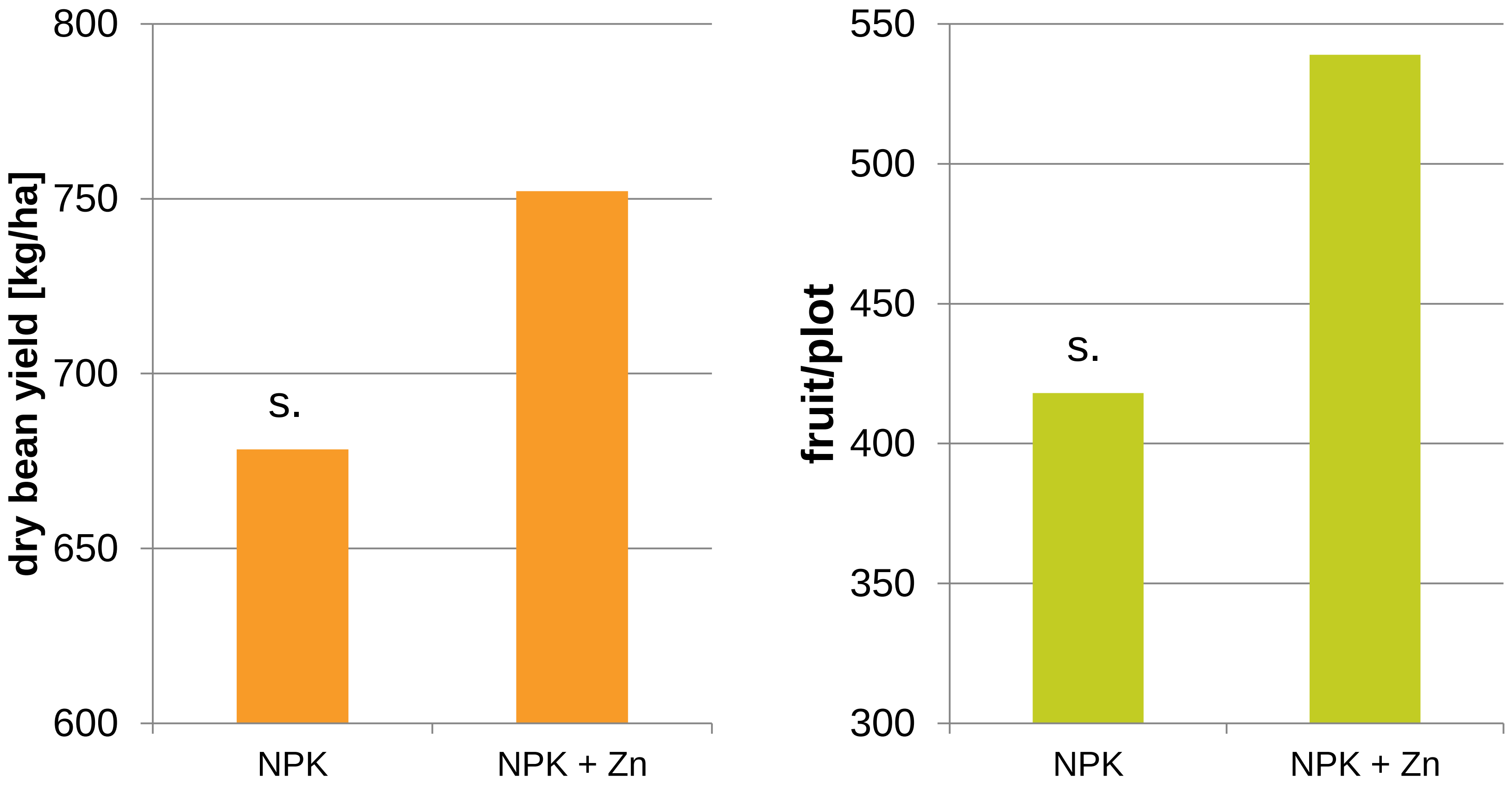
Effect of soil boron application on cocoa yield
- Nigeria



B application to the soil is efficient.
6.2 g B/tree applied around the stem base, other nutrients applied at same level.

source: Ojeniyi. 1981b

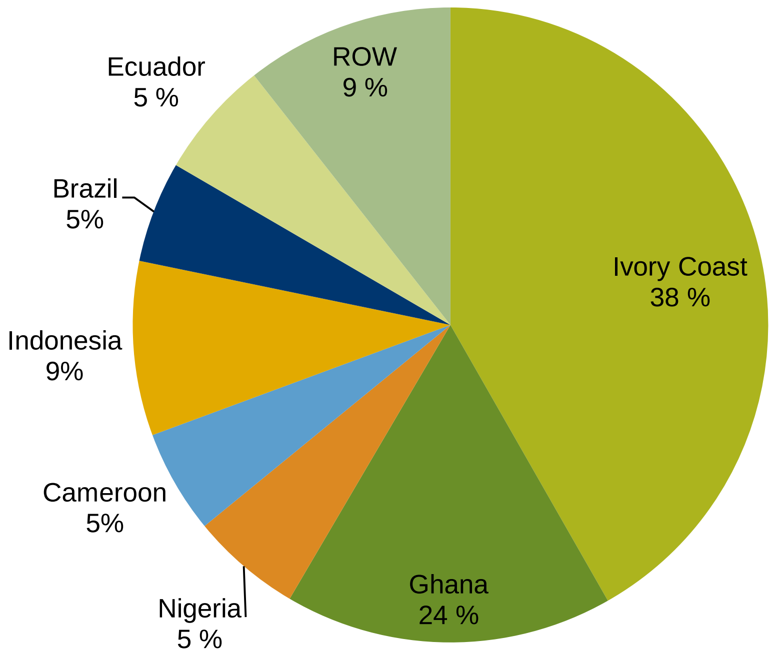
Impact of zinc application on cocoa yield - Brazil



source: Morais, 1998a

World production is over 4 Mill. Tons Cocoa beans. West Africa represents 70 % of the total.

- Cote Ivoire + Ghana = 2,5 Mill. Tons
- Indonesia + Nigeria + Cameroun + Brazil + Ecuador = 1,3 Mill. Tons
- ROW= 0,5 Mill. Tons



Source: LMC report 2014, data from 2013/2014

Uptake of nutrient removed to produce 1 t/ha of cocoa with shell included

N	P_2O_5	K_2O	MgO	CaO
38.7	13.9	67.8	11	8.9

Nutrient (Kg) Uptake to produce 4 million tons of cocoa (1,233TM)

	N	P_2O_5	K_2O	MgO	CaO
Nutrients	160.000	58.600	271.200	44.000	35.600
KTM Tons of fertilizers with classic raw materials (urea , nitrate, dap , mop, kieserite, calcium nitrate)	348	120	452	176	137

Nutrient(Kg) Uptake by a whole mature plant (1100 trees/ha)

N	P_2O_5	K_2O	MgO	CaO
453	114	788	221	540

Nutrient Uptake (Tons) by a whole mature plant for 2 million of hectares (11,246)

	N	P_2O_5	K_2O	MgO	CaO
Nutrients	906.000	228.000	1.576.000	44.200	1.080.000
KTM Tons of fertilizers with classic raw materials (urea , nitrate, dap, mop, kieserite, calcium nitrate)	1970	495	2827	1700	4254

Which is a fertilizer and an acidity regulator?

Material	Fórmula Química	Solubilidad (g/l)
Carbonato de calcio	CaCO3	0,014
Carbonato de magnesio	MgCO3	0,106
Hidróxido de calcio	Ca(OH)2	1,85
Hidróxido de magnesio	Mg(OH)2	0,09
Oxido de magnesio	MgO	0,086
Magnesil	%Si (SiO2)	0,34
Daphos	%Si (SiO2)	1,19
Magneserita	%Si (SiO2)	0,11
Yeso	CaSO4	1,34
Kmag	MgSO4xKSO4	280
Nitromag	NH4NO3xMgOCaNO3	330
Kieserite	MgSO4	340
Cloruro de Potasio	KCl	350
Fosfato diamónico	DAP	580
Urea	CO(NH2)2	1000
Nitrabor	CaNO3	1300
Nitrato de Amonio	NH4NO3	1900

Considerations

- Relationship of nutrients in cocoa production: 1:0,3:1,7:0,5:1,2+EM
- Cocoa plantations fertilized with the proportion of nutrients?
- We are "exploiting" the soil correctly ?
- We are degrading our soils and environment?
- Applying fertilizers are free of heavy metals?
- Apply organic fertilizers and salinity and acidity correctors free of heavy metals ?
- Fertilizers that governments "donate" to producers are are correct?
- Its balance of nutrients are good ?

Considerations

- what kind of soil they want to leave their farms for the future of their families?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Thank you