Potash Review

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Subject 2 **No. 4/1988**
Plant Physiology, Plant Analysis
3rd suite

Anatomical study and cytological demonstration of potassium and chlorine flux associated with oil palm and coconut stomatal opening (Etude anatomique et mise en évidence cytologique des mouvements de potassium et de chlore associés à l'ouverture des stomates de palmier à huile et de cocotier)

Braconnier S.[1] *and d'Auzac J.*[2]

Source: Oléagineux *40*, 11,547–551 (1985)

Summary

Oil palm and coconut stomata are composed of 6 cells (2 guard cells + 4 subsidiary cells). Guard cell chloroplasts contain starch. On stomatal opening, there occurs a potassium flux into stomatal cells and also a chlorine flux from lateral subsidiary cells into the guard cells. Thus, chlorine perhaps plays a double role in oil palm and coconut stomatal opening (it can result in a lateral subsidiary cell turgidity fall and a stomatal cell turgidity increase).

1. Introduction

In 1971 *Ollagnier and Ochs [1]* showed for the first time that chlorine should be considered an essential element in oil palm mineral nutrition. Since then, numerous experiments have confirmed that chlorine nutrition plays a major role in perennial oil crop yield improvement, especially in coconut *[2–6]*. For the latter, chlorine deficiency brings about a decline in growth, a reduction in nut production per tree and copra content per nut, along with lower tolerance to drought and certain diseases. For oil palm, poor chlorine nutrition influences bunch production (reduction in average weight) and its structural

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composition (less fruit, lower weight per fruit and per kernel). Correcting this deficiency can increase production by about 15% in oil palm and up to 50% in coconut [7, 8].

Understanding the physiological role(s) of chlorine in plants therefore seems to be of utmost importance. The stomatal complex could be one of the most important areas of activity for the Cl^-ion. In effect, stomata control vital gaseous exchanges. In certain plants, the Cl^-ion can play an important role in stomatal regulation [9].

Quantitatively speaking, an influx of K^+ on stomatal opening is the most important phenomenon. This can result from a change in trans-membrane potential, caused by the pumping of protons (efflux), the pumping of anions (influx) or the endogenous biosynthesis of organic acids, depending on the plant. Hence, species such as *Allium cepa,* whose guard cell chloroplasts lack starch, must be distinguished from other species with starch in the guard cells *(Vicia faba, Commelina communis).* In the former (onion), the influx of anions on stomatal opening (chiefly Cl^-) is in effect much greater than that of other species which can synthesize organic anions *in situ* by means of glycolysis and starch hydrolysis.

The objective of this study is to find out whether starch is present in oil palm and coconut stomatal cell chloroplasts and to determine the role played by Cl^- ions in stomatal opening and closing mechanisms. Peanut and onion are used as reference plants in this study.

2. Methods and results

The examination of epidermal sections under an optical microscope reveals anatomical differences in the stomatal complex of the four plants considered. Hence, oil palm and coconut stomata are composed of 6 cells: 2 guard cells and 4 subsidiary cells, of which 2 lateral and 2 polar; whilst peanut stomata have 4 cells, 2 guard cells and 2 subsidiary cells. Finally, the onion seems to be composed of only 2 guard cells (Figures 10, 12, 14, 16).

To detect chloroplasts in the guard cells, episcopic techniques are used. The epidermal sections, mounted between two slides, are subjected to light with wavelengths ranging from 350 to 450 nm and the chlorophyll, activated by this light, emits a characteristic red fluorescence. Figures 1–4 (Plate 1) confirm that chlorophyll is present in the guard cells of all four plants under consideration. Nonetheless, oil palm and coconut stomatal cell chloroplasts do not appear to be as fluorescent as those of peanut or onion.

The epidermal sections are then treated with a potassium iodide reagent, which makes the starch visible (Figures 5–8 on Plate I). This is present in all the stomatal cells, except those of the onion. Hence, it is probable that oil palm and coconut stomata function differently. Determining the presence of K^+ ions with sodium cobaltinitrite [11] confirms that a K^+ influx is associated with stomatal opening. (Figures 9–12 on Plate I and Figures 13–16 on Plate II). The silver nitrate technique is used to make Cl^- visible *[11].* In peanut (Figures 20, 24 on Plate II) which is very tolerant to chlorine *[12],* stomatal opening does not seem to modify Cl^- anion distribution. Conversely, in oil palm, coconut and onion, chlorides accumulate in the guard cells of open stomata (Figures 21, 23 on Plate II). In oil palm and coconut, chlorine plays a

double role in stomatal osmotic movement. When stomata are closed, it is found in the subsidiary lateral cells (Figures 17, 18 on Plate II), helping to maintain cell turgidity, which prohibits stomatal opening. On the other hand, when stomata are open, Cl^- migrates towards the guard cells, simultaneously reducing subsidiary lateral cell turgidity and increasing that of the guard cells, which encourages stomatal opening. Hence, in oil palm and coconut, even if the Cl^- influx in stomatal cells during opening is lower than that of the onion, its importance is no less, considering the double role Cl^- can play in osmotic movement. This is confirmed by the fact that reducing Cl^- in the treatment medium modifies the degree of stomatal opening. It can be recalled that in 1980, *Schnabl and Raschke [12]* showed that if Cl^- ions in the treatment medium were replaced with impermeable anions (iminodiacetate), onion stomata no longer opened. Applied to coconut, this experiment reduces stomatal opening by about 27%. Average opening is 6.12 ± 0.23 µm (after a 3-hour pretreatment in a MES 10 mM buffer, pH 3.9, then 4 hours in a KCl 100 mM solution, pH 6.3, under light in CO_2 impoverished air), whilst it is only 4.45 ± 0.16 µm in a chlorine-free medium (based on 420 measurements). In oil palm, no statistically significant reduction in stomatal opening was recorded. Hence it would seem that Cl^- plays a more important role in stomatal action in coconut than in oil palm, at least under our experimental conditions, where a certain quantity of endogenous Cl^- was recorded in both plants.

To conclude, techniques using optical microscopes enable the following to be determined:

1) The presence of chloroplasts and starch in oil palm and coconut stomatal cells, which provides leeway for a possible synthesis of endogenous organic acids;

2) An influx of potassium to the guard cells of coconut, oil palm, peanut and onion;

3) A Cl^- flux from the lateral subsidiary cells to the guard cells during stomatal opening in oil palm and coconut. This flux is considerable in coconut, where the absence of Cl^- in the treatment medium reduces stomatal openings by about 27%. This Cl^- influx could occur together with the possible synthesis of organic acids mentioned above. The considerable Cl^- effect in coconut can arise from its double role during stomatal opening (reduction of subsidiary lateral cell turgidity and increase in that of the guard cells).

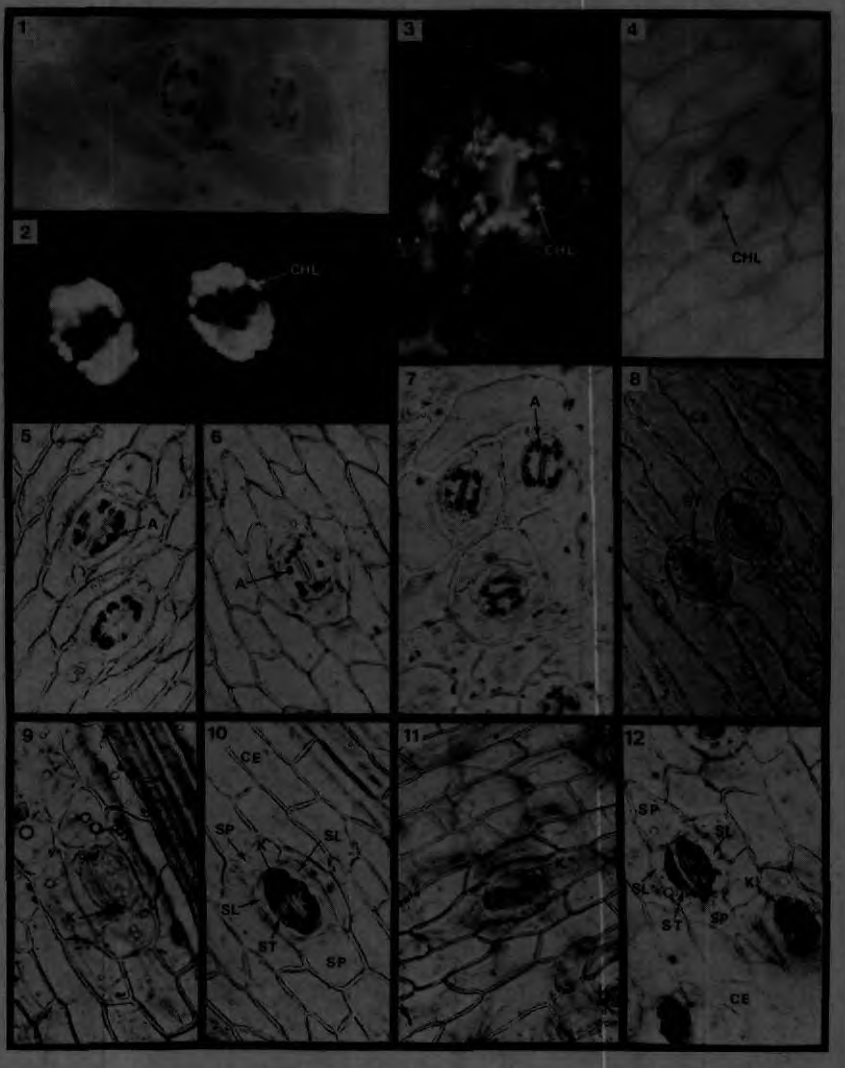

Fig. 1 to 4 Stomatal cell chloroplasts fluorescence from peanut (1), onion (2), coconut (3) and oil palm (4). Figures are obtained from color negatives for peanut and oil palm, and from color slides for onion and coconut.

Fig. 5 to 8 Guard cell chloroplast starch stained with potassium iodide reagent in coconut (5), oil palm (6), peanut (7) and onion (8).

Explanation of figures: ST, stomatal cell; SL, lateral subsidiary cell; SP, polar subsidiary cell; CS, epidermal cell; CHL, chloroplast; A, starch; K, potassium ion; CL, chlorine ion.

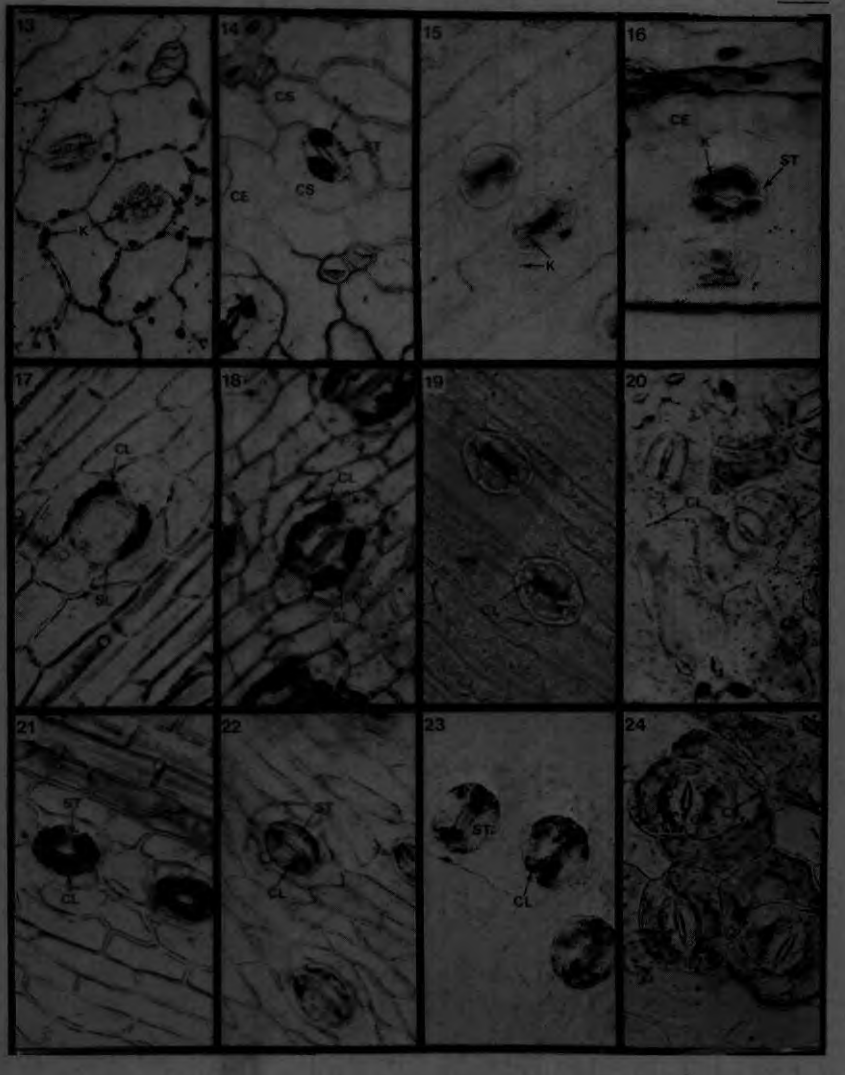

Fig. 9 to 16 Study of potassium movement by staining with sodium cobaltinitrite. For Figures 9 (coconut), 11 (oil palm), 13 (peanut) and 15 (onion), epidermal sections are stained after treatment for 4 h on distilled water in the dark; stomata are closed. In Figures 10 (coconut), 12 (oil palm), 14 (peanut) and 16 (onion), Cl^- is stained after a treatment to open stomata 4 h on KCl solution 100 mM pH 6.3, in the light, under CO_2 free air.

Fig. 17 to 24 Cl^- ions are stained by silver nitrate. Treatments are the same as the former ones. In addition, sections go through a pretreatment of 3 h in a MES (2 N morpholino ethane sulfonic acid) buffer 10 mM, pH 3.9, to destroy epidermal cells, this does not affect stomatal cell integrity. Figures 17, 18, 19, 20 show respectively closed stomata of coconut, oil palm, peanut and onion. Figures 21, 22, 23 and 24 show respectively the same but opened stomata.

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Subject 4 **No. 4/1988**
Plant Nutrition
3rd suite

Correction of lime-induced chlorosis by application of iron and potassium sulphates

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Source: Fertilizer Research *13*, 2, 161–167 (1987)

Summary

The effects of iron sulphate in an acid urea medium, potassium sulphate, three mixtures of potassium sulphate with iron sulphate, a mixture of potassium chloride with iron sulphate, ammonium sulphate with nitrification inhibitor (DCD) plus iron sulphate and, finally, sequestrene, in correcting iron chlorosis in peanuts *(Arachis hypogea)* on a soil containing 65% $CaCO_3$, pH 7.6 known to induce chlorosis, were tested in pot experiments. The potassium sulphate-iron sulphate mixtures were as effective as sequestrene or more so in correcting chlorosis. The potassium chloride mixture and the ammonium sulphate-DCD-iron sulphate mixture were less effective, the latter probably because of ammonium toxicity. Iron sulphate or potassium sulphate alone had no effect. The effective correction of iron chlorosis requires simultaneous application of iron and potassium sulphates.

1. Introduction

Plants growing in highly calcareous soils develop in many instances chlorotic symptoms accompanied by yield reduction. This lime-induced chlorosis is related to iron deficiency in the plant, caused by limited iron uptake or by its inactivation in the plant *[6]*. Iron nutrition of plants in calcareous soils was reviewed *[2]*. Effective soil applications of iron are in chelated forms. This practice is expensive and applicable only to high-value crops. For correction of chlorosis in field crops economic amendments comparable to conventional fertilizers would be necessary.

Increasing iron concentration in soil solution increases its uptake by plants *[8]*. Some results indicate that application of high rates of $FeSO_4$ (up to 560 kg Fe/ha) may correct chlorosis *[10, 5]*. An ample supply of cations such

as K^+ or NH_4^+ in the root medium should induce an increased cation uptake and with it enhance exudation of H^+ ions. This should reduce the pH of the rhizosphere. Reducing the pH of the rhizosphere would have a favourable effect on iron solubility and uptake by plants *[2]*. Application of ammonium sulphate with a nitrification inhibitor to a highly calcareous soil reduced iron chlorosis in peanuts *[7]*. However, ammonium nitrogen nutrition of plants may have toxic effects. It was confirmed that ammonium nitrogen uptake reduces plant growth compared with nitrate nitrogen *[12]*.

Uptake of iron by corn plants was stimulated by the presence of increasing levels of K_2SO_4 *[11]*. KNO_3 had a much smaller effect. The pH of the SO_4 solution dropped from 9.2 to nearly 4, while that of the NO_3 solution dropped from 8.4 to 6.5. Nitrate is taken up at a rate similar to that of K, which is faster than that of SO_4. Thus, NO_3 causes a smaller decline of the pH.

Potassium fertilization at rates of 135 to 405 mg K/kg soil ameliorated iron chlorosis in peanuts grown in a highly calcareous soil *[1]*. K_2SO_4 was more effective than KCl. This was attributed to the cation/anion balance of ion uptake and consequent rhizosphere acidity. A negative interaction between iron and cation uptake is indicated. In some plants Fe deficiency was shown to reduce cation uptake, mainly potassium *[4]*.

According to the cited findings, it seems that a combined application of $FeSO_4$ and K_2SO_4 should be an effective and economic means for correcting lime-induced iron chlorosis. In our experiments peanuts were taken as the test plant. They are classified within the group of crops highly susceptible to chlorosis *[9]*.

2. Materials and methods

Two greenhouse experiments, the first preliminary, were performed for testing various combinations of potassium and ammonium salts with iron sulphate, as a means of correcting lime-induced chlorosis. The experimental soil was a pale Rendzina clay loam, according to US Soil Taxonomy a Lithic Xerorthent *[3]*, having 65% $CACO_3$ and a pH of 7.6 in a soil-water paste. The soil had a high level of available potassium, according to *Woodruff's* method *[6]*, namely $\Delta F = -2900$ cal/mol. The same soil was used in *Barak and Chen's [1]* experiments. Peanuts *[Arachis hypogea) cv* Shulamit were grown in 3 l pots. Experiment 1 was performed late in autumn, which is a late season for peanut growth. The plants developed very clear differences of chlorotic symptoms between treatments, but growth was slower than in Experiment 2. Plants in Experiment 2 were sown in late spring. Fertilizer materials used in the experiments and their composition are listed in Table 1. Materials were in powder form (except where stated differently). They were mixed with the whole soil volume in a pot. Rates of application of Fe and K per treatment are listed in Table 3. All pots received 1 g P as concentrated superphosphate and 0.5 g N as $Ca(NO_3)_2$, except in the $(NH_4)_2SO_4$ treatments where the nitrate was added, to bring N application to 0.5 g N. De-ionized water was added frequently to field capacity by weight. All treatments were in four replicates.

Degree of chlorosis in plants was identified by the chlorophyll content of leaves. During the growth period two samplings for determination of chlorophyll content were taken by cutting out of leaves 10 ± 0.6 cm-diameter dis-

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Table 1 Composition of fertilizer materials

Material	Symbol	Content, %		
		Fe	K	N
Experiment 1				
Urea sulphate+$FeSO_4$	USFe	7.2		2.3
K_2SO_4+$FeSO_4$	KSFe (1)	7.0	29.2	
Experiment 2				
K_2SO_4+$FeSO_4$	KSFe (7)	7.0	18.8	
K_2SO_4+$FeSO_4$	KSFe (10)	10.0	17.7	
K_2SO_4+$FeSO_4$	KSFe (14)	14.0	10.6	
KCl+$FeSO_4$	KClFe	11.6	19.9	
$(NH_4)_2SO_4$+DCD*+$FeSO_4$	ASFe	9.5		10.1
Experiment 1 and 2				
K_2SO_4	KS		44.8	
Sequestrene (liquid)**	Seq.	6.0		

* DCD=Dicyandiamide, a nitrification inhibitor.
** Chelated iron compound.

kettes per pot. The leaf tissues were extracted in 95% ethanol for one hour at 70°C in the dark. Optical density of the solution was measured in a spectrophotometer at 654 nm and chlorophyll concentration calculated *[13]*. At the end of about eight weeks of growth the plants were cut, and dry weight was determined.

3. Results and discussion

Chlorotic symptoms in peanut plants were identified by measuring chlorophyll concentration in leaves and by plant yield. Chlorophyll concentrations at two dates of sampling and dry matter yield of plants for Experiment 1 are given in Table 2. Visually, plants growing in the check treatment showed severe chlorotic symptoms, whereas those that received sequestrene application were green and not chlorotic. This is reflected in the difference in chlorophyll concentration of leaves and plant yield between these treatments. Results in Table 2 show that iron sulphate applied in an acid medium had a slight correcting effect on chlorosis. That effect increased with increasing levels of application. Potassium sulphate at the one level of application had no correcting effect. Yield results for the check treatment, for the iron sulphate and for the potassium sulphate applications do not differ significantly. Application of a mixture of iron sulphate with potassium sulphate, giving about the same rates of iron application as the iron sulphate treatments, corrected chlorotic symptoms and improved plant yields significantly.

The second experiment was designed according to findings of the first, preliminary, experiment. It included several ratios of iron sulphate to potassium sulphate. In one treatment potassium chloride was tested and in another ammonium sulphate, both mixed with iron sulphate. Check treatments

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Table 2 Chlorophyll content of leaves (s.e.) at two sampling dates and dry matter yield of peanut plants. Experiment 1

Material	Material applied g/pot	Chlorophyll, mg/cm^2 Weeks after emergence		Dry matter yield g/pot
		5	8	
Check	—	0.6 (0.0)	0.2 (0.0)	2.6
USFe	1.25	1.0 (0.2)	0.3 (0.2)	2.8
	2.50	1.1 (0.0)	0.5 (0.1)	2.9
	3.75	1.3 (0.3)	0.5 (0.3)	2.9
	5.00	1.8 (0.1)	0.8 (0.1)	2.9
KSFe (I)	1.25	1.4 (0.1)	0.7 (0.1)	3.6
	2.50	2.4 (0.3)	1.0 (0.3)	4.2
	3.75	2.1 (0.2)	1.3 (0.1)	4.9
	5.00	2.8 (0.3)	1.4 (0.1)	4.7
KS	1.00	0.6 (0.1)	0.3 (0.1)	2.9
Seq.	0.025	3.7 (0.4)	2.6 (0.1)	5.7
	Sign. level			0.005
	l.s.d.			0.6

Table 3 Chlorophyll content of leaves and dry matter yield of peanut plants. Experiment 2

Material	Material applied g/pot	K appl. mg/pot	Fe appl. mg/pot	Chlorophyll, mg/cm^2 Weeks after emergence		Dry matter yield g/pot
				5	8	
Check	—	—	—	0.64	0.00	3.3
KSFe (7)	1.5	340	105	3.15	2.71	10.3
	3.0	680	210	3.33	4.79	10.2
	4.5	1020	315	5.93	11.75	14.3
KSFe (10)	1.0	177	100	2.85	2.53	8.9
	2.0	355	200	4.16	5.91	12.0
	3.0	532	300	5.33	8.03	14.7
KSFe (14)	1.5	160	210	4.00	4.81	11.4
	2.25	240	315	5.41	6.41	14.1
	3.25	346	455	5.98	9.21	14.5
KClFe	0.9	179	105	1.38	1.73	4.2
	1.8	358	210	2.59	2.83	8.3
	2.7	537	315	3.89	3.61	8.8
ASFe	1.05	—	100	1.56	1.24	5.7
	2.10	—	200	1.95	3.06	8.4
	3.15	—	300	1.91	2.35	5.8
KS	0.67	300	—	0.85	1.03	4.3
	1.34	600	—	0.97	0.97	5.4
	2.01	900	—	0.97	0.64	4.4
Seq.	0.025	—	1.5	5.73	2.56	11.8
	Sign. level			0.005	0.005	0.005
	l.s.d.			0.23	1.22	2.0

included: no iron or potassium, application of potassium sulphate only and sequestrene application. Results presented in Table 3 show that iron supplied at a rate of 300 to 455 mg/pot (120 to 130 µg Fe/g soil), in any of the three iron sulphate-potassium sulphate mixtures corrected chlorotic symptoms in peanuts growing for five weeks. Similr results were obtained with sequestrene application. Three weeks later iron sulphate-potassium sulphate mixtures were more effective in correcting chlorosis and in producing plant yield than sequestrene. Relative effectiveness of the mixture is presented in Figure 1. It appears that within the range of K studied, there was no advantage to

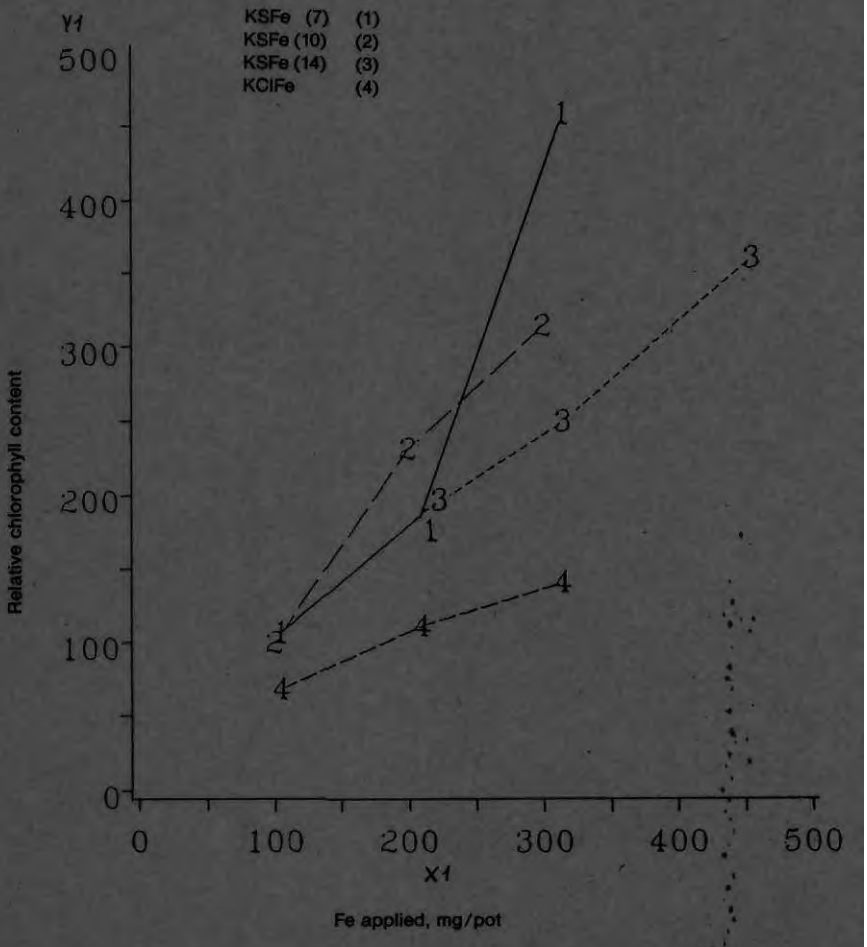

Figure 1 Relative effectiveness of potassium and iron sulphate mixtures and of potassium chloride and iron sulphate mixture in correcting chlorosis in peanut plants, 8 weeks after emergence. Chlorophyll content in sequestrene-treated samples=100.

increasing the ratio of K to Fe. The mixture containing potassium chloride was less effective than the corresponding one containing potassium sulphate. This result emphasizes the role of the anion accompanying potassium in activation of iron. The chloride anion is taken up faster than the sulphate, and it was therefore assumed *[11]* that uptake of sulphate should lower the pH of the rhizosphere more than uptake of chloride. Ammonium sulphate with a nitrification inhibitor-iron sulphate mixture corrected chlorotic symptoms to some extent, but at the same time had a toxic effect. Leaf tips were scorched, probably due to ammonium accumulation in the plant. The higher level of application depressed crop yield and chlorophyll level in leaves. This result indicates that use of ammonium nutrition is not very effective for correcting chlorosis *[7]*. Potassium sulphate application without addition of an iron compound had a very small effect on chlorosis correction or on peanut plant yield. This result differs from that obtained by *Barak and Chen [1]*. In our experiment the soil volume was about six times larger than in theirs. It seems that in a larger soil volume the acidification effect caused by potassium uptake by roots is not sufficient for alleviating chlorosis and that, in addition, an ample supply of iron is required for correcting chlorotic symptoms.

In conclusion, experimental results confirm the assumption made in the Introduction, that an enhanced supply of potassium, accompanied by an application of iron, corrects chlorotic symptoms in plants, and further, that the sulphate accompanying potassium is more effective than chloride and that ammonium is less effective in correcting chlorosis than potassium, probably because of toxicity of ammonium in the plant. The results indicate that application of a potassium sulphate-iron sulphate mixture may be as effective as iron chelates in correcting lime-induced chlorosis in plants.

Acknowledgements

Thanks are due to *Fertilizers and Chemicals Ltd., Haifa,* for partially supporting this research.

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Subject 4 **No. 4/1988**
Plant Nutrition
4th suite

Estimate of macronutrient uptake and removal by the ten principal crops of São Paulo State[1]

Hiroce, R.[2]

Source: O Agronômico, Campinas, SP, *37*, 3, 161–165 (1985)

An estimate of the quantities of fertilizers needed to replace nutrient removals and so maintain fertility can be obtained from a knowledge of plant composition. Though plant composition varies with variety and soil type, average data together with area under crop and average yield should suffice to give estimates accurate enough to form a basis for fertilizer programmes designed to maintain or improve fertility.

Statistics of area planted and crop yield (Table 1) were supplied by the *Institute of Agricultural Economy*. Data for crop composition were obtained from national and international sources as listed in the bibliography and are given in Table 2.

Total nutrient uptake and quantities of nutrients removed in the harvested product expressed in 1000 t were as follows:

Nutrient	*Total uptake*	*Removed at harvest*
N	837	312
P_2O_5	182	83
K_2O	806	288
CaO	476	83
MgO	182	59
S	85	34

1. This paper belongs to the activities of the project 'Sistema de Recomendação de Corretivos e Fertilizantes para Culturas no Estado de São Paulo'.
2. Research Worker, Section of Soil Fertility and Plant Nutrition, Agricultural Institute, Campinas, SP/Brazil.

Total uptake over estimates the fertilizer need because much nutrient contained in the vegetative parts is returned to the soil. Application of the amounts removed in harvested products will not alone be sufficient to make full restitution and some addition must be made to restore losses by leaching, etc. Nitrogen removal by leguminous crops (peanut and soybean) can be discounted since they obtain their nitrogen needs by symbiosis.

Raij [1985], on the basis of soil analysis, estimated the lime and fertilizer requirements of São Paulo State in 1983 to be in 1000 t: lime: 9011, N: 516, P_2O_5: 374, K_2O: 464.

It would appear that the recommendations for N, P_2O_5 and K_2O (in total about 1.4 million t) are about double the quantities removed at harvest (0.7 million t). It is thought that agricultural production in São Paulo State could be doubled without any increase in cultivated area if the recommended amounts of lime and fertilizers were applied.

Table 1 Cultivated area, yield and production for the ten principal crops of São Paulo State in 1983

Crop	Cultivated area (1000 ha)	Yield (t/ha)	Total production (1000 t)
Sugarcane	1734	76	131 784
Maize	1166	2.600	3031
Coffee	889	1.229	1092
Oranges	563	16	9008
Beans	496	0.585	290
Soybean	470	2.055	965
Rice	334	1.848	617
Cotton	309	1.504	464
Peanut	177	1.365	241
Wheat	142	1.350	191

Table 2 Quantities of macronutrients taken up and removed by the ten principal crops of São Paulo State (1000 t)

Crop	Plant part	N	P_2O_5	K_2O	CaO	MgO	S
Sugarcane	Stalk	121	27	174	48	35	19
	Other parts	110	18	124	33	26	9
	Total	231	45	298	81	61	28
Maize	Grains	42	24	24	4	8	5
	Other parts	52	5	38	18	14	4
	Total	94	29	63	22	22	9
Coffee	Grains	18	4	28	3	2	1
	Other parts	198	32	194	171	44	21
	Total	216	36	223	174	46	22
Oranges	Fruit	15	3	22	24	3	1
	Other parts	30	4	10	93	4	–
	Total	45	7	32	107	7	1
Beans	Grains	10	1	4	1	1	1
	Other parts	7	2	12	6	3	1
	Total	17	3	16	7	4	2

Crop	Plant part	N	P_2O_5	K_2O	CaO	MgO	S
Soybean	Grains	62	12	19	4	4	1
	Other parts	78	13	31	23	17	2
	Total	140	25	50	27	21	3
Rice	Grains	9	4	2	1	1	1
	Other parts	15	11	39	8	4	1
	Total	24	15	41	9	5	2
Cotton	Bolls	10	3	10	5	3	3
	Other parts	19	3	5	25	4	8
	Total	29	6	15	30	7	11
Peanut	Grains	13	2	1	1	1	1
	Other parts	5	1	8	9	3	1
	Total	18	3	9	10	4	2
Wheat	Grains	12	3	4	2	1	1
	Other parts	11	10	55	7	4	4
	Total	23	13	59	9	5	5
Total	Harvested parts	312	83	288	83	59	34
	Other parts	525	99	518	393	123	51
	Total	837	182	806	476	182	85

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Potash Review

Publisher: International Potash Institute, CH-3048 Worblaufen-Bern/Switzerland
Phone 31/58 53 73, Telex 912 091 ipi ch

Subject 2 **No. 4/1988**
Bibliography
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Plant physiology, plant analysis

4332 *Huber, D.M. and Arny, D.C.*

Interactions of potassium with plant disease

Proc. PPI, ASA, CSSA, SSSA, NFDC, IFDC and FAR Symp., Atlanta/Georgia, 467–488, 1985

Although few diseases can be totally eliminated by a given type of fertilizer, the severity of most diseases can be greatly reduced by proper nutrition, and the chemical, genetic, or biological control of many plant pathogens can be enhanced, even though none of the nutrient elements completely alters the inherent reaction of a plant to a pathogen. Unfortunately, conclusions from some nutrient studies have been interpreted to mean that withholding certain nutrients would prevent disease. Such practices have seriously reduced crop yields and frequently had the same effect on productivity as severe infection would have had. There is no reason to starve the plant into an unproductive state to escape disease. Obvious nutrient deficiencies that limit yield or quality should be corrected and nutrition should be used in conjunction with other practices, such as disease resistance, crop rotation, weed control, and insect management as necessary to promote maximum plant productivity.

Manipulation of K to enhance disease resistance should recognize that:

1. No nutrient controls all diseases or favors disease control on any one group of plants; therefore, all control practices should be integrated for optimum plant growth and production.
2. Damage or predisposition imposed by early nutrient deficiencies or imbalances may not be offset by later applications.
3. The nutritional balance is frequently as important as the level of a single nutrient.
4. Fertilizing may not increase the actual resistance of plants as much as it stimulates growth of the crop to minimize disease damage.
5. Local environmental conditions such as moisture, pH, temperature, previous cropping, and rhizosphere microbial activity may enhance or nullify the effectiveness of K in reducing specific diseases.
6. The greatest disease reduction from K nutrition has been observed with varieties with some degree of inherent resistance.

If all these situations are taken into consideration, it is apparent that K is an important management tool in our arsenal against disease.

4333 *Usherwood, N.R.*

The role of potassium in crop quality

Proc. PPI, ASA, CSSA, SSSA, NFDC, IFDC and FAR Symp., Atlanta/Georgia, 489–513, 1985

The role of K in crop quality has been documented by scientists throughout the world. The influence exists for crops grown in temperate and humid regions, for legumes and nonleguminous plants, for annual and perennial crops, and for other crops grown as *food, fiber, or ornamental purposes.*

Parameters for measuring the influence of K on crop quality reflect the specific functions of K in plant growth. For example, the influence of K on improved protein quantity and quality in crop production is a reflection of the role of K in protein synthesis and N use efficiency. Quality seed and improved plant standability reflect the role of K in disease resistance and substrate translocation. Increased stand longevity of forages can result from reduced winter injury and greater tolerance to rigorous harvest schedule. The influence of K can also be indirect as a result of its positive interaction with other nutrients and production practices. Other attributes, such as produce appearance, shelf life, size, taste, and texture, are other quality components influenced by K and are of significance in the marketplace.

The quantity of K required to obtain high yields and quality varies with soils and crop requirements for K and the growth environment. Research indicates that in some instances the amount of applied K required for optimum yield is also sufficient for obtaining desired levels of crop quality. In other instances, however, the desired level of crop quality and economic return is attained at rates exceeding those required for the maximum crop yield. This influence has been documented for crops such as tobacco, turf, ornamentals, and some food and fiber crops.

The extent of the influence of K as measured through research seems to be guided not only by the amount of available K^+ from fertilizer and the soil but also by environmental influences, genetic variability, production level, interacting production practices, and timeliness of operation decisions. In many studies, parameters evaluating treatment effect on crop quality have priority. With rising research costs and the growing need to obtain the maximum information from research, quality parameters are receiving greater recognition. The interdisciplinary team approach to maximum crop yield *research is the best approach for maximum yield of knowledge from research.*

4334 *Muthuswamy, P., Thalamuthu, S. and Narayanan, A.*

Role of potash on the incidence of blast in rainfed finger millet *(Eleusine coracana* G.)

Journal of Potassium Research *1*, 4, 211–213 (1985)

Influence of levels of nitrogen, phosphorus and potassium on the incidence of blast disease *(Pyricularia setariae)* of finger millet crop was studied under rainfed conditions. Increasing amount of nitrogen had a markedly aggravating effect while potash application significantly reduced the severity of the blast incidence.

4335 *Goos, R.J.*

Effects of KCl fertilization on small grains in North Dakota

Chloride and Crop Production, PPI Special Bulletin No. 2, 52–61 (1986)

There is a definite history of response of barley to KCl fertilization in North Dakota. A chloride-disease interaction seems to explain these responses. Many questions have arisen because of these findings. On a theoretical level, it is not known *why* modest rates of KCl reduce common root rot (CRR) of barley. Fertilization with KCl significantly reduces the nitrate content of barley plants, and this reduction in nitrate content may reduce barley susceptibility to common root rot. On a practical level, more questions remain: How do other small grains infected with CRR *(e.g.*, durum wheat, hard red winter wheat, hard red spring wheat) respond to KCl? Does KCl reduce leaf disease severity *(e.g.*, tan spot, leaf rust, spot blotch)? What is the minimum rate of KCl needed? Are there residual effects of Cl? Does placement *(e.g.*, band *vs.* broadcast) influence Cl^--disease interactions?
It will take several years to find answers to these questions. Research with CRR/fertilizer interactions is tedious, and progress is slow. From our experience, 6 or fewer treatments, 5 or more replicates, and strict double-blind rating systems are needed to reduce experimental error to acceptable levels. Similar experimental constraints should be considered by those beginning CRR/fertilizer research.

4336 *Sij, J.W., Turner, F.T. and Whithney, N.G.*

Suppression of anthracnose and phomopsis seed rot on soybean with potassium fertilizer and benomyl

Agronomy Journal *77*, 4, 639–642 (1985)

Recent studies linking K with less disease in certain crops have stimulated interest in the beneficial aspects K may play in plant disease protection. The objectives of this 3-year study were to evaluate the role of K fertilizer on anthracnose [*Colletotrichum dematium* (Pers. ex Fr.) Grove var. *truncatum* (Schw.) Arx.] and phomopsis seed rot *(Phomopsis* sp.) development in field-grown soybean plants [*Glycine max.* (L.) Merr.] and to measure the interaction of foliar-applied benomyl fungicide with soil-applied K fertilizer. The soil, a Typic Agriaquoll, contained low (215 to 278 kg/ha) and high (11 to 96 kg/ha) levels of available K and P, respectively. The experiments included six levels of K, three levels of P fertilizer, and two levels of benomyl fungicide on 'Davis' soybean harvested at maturity and 4 weeks later. Anthracnose disease ratings decreased significantly as K rates increased to the maximum of 450 kg/ha. Benomyl and K+benomyl reduced anthracnose substantially more (about 60%) than did K alone. The action of K fertilizer on anthracnose control appeared to be additive to that afforded by benomyl when the soil contained low to medium K. Increasing K fertilizer significantly increased soybean yield by about 700 kg/ha when 220 kg/ha of K fertilizer was applied. Application of benomyl provided an additional yield increase of about 300 kg/ha except at the highest K level. Increasing K up to 330 kg/ha reduced delayed harvest yield losses caused by shattering and weathering. Benomyl and K+benomyl treatments minimized delayed harvest losses, which peaked at a K level of about 220 kg/ha. Phosphorus fertilizer failed to increase yield or prevent shattering. Increasing K reduced *Phomopsis* sp. in first-harvest seed from 35% to about 1% and in second-harvest seed from about 52 to 28% in plots receiving no K fertilizer and 450 kg/ha of K, respectively. The addition of benomyl suppressed this pathogen further in first-harvest seed from 12% infected

seed to 1% and in second-harvest seed from 40 to 18% in plots receiving no K fertilizer and 450 kg/ha of K, respectively. Phosphorus, however, appeared to slightly enhance *Phomopsis* sp. development. The effects of residual fertilizer on anthracnose development and yield were evident the following soybean growing season. Although pathogen pressure and environmental conditions play a major role in disease development in soybean, it should be recognized that soil K level can also be an influencing factor.

4337 *Baskaran, P.*

Potash for crop resistance to insect pests

Journal of Potassium Research *1,* 1, 81–94 (1985)

The role of potassium as an inducer of resistance to insect pests is discussed. Some studies have indicated that K as a major plant nutrient can act as an inducer, especially at enhanced rates of application, of desirable biochemical alterations in the host plants to the detriment of normal feeding and development of the insects. Detailed studies showed that with enhanced application of K the treated plants were not preferred by rice insects. It is further indicated that the beneficial effect of potash appears to largely depend on a number of factors, such as its availability in soil and the uptake capacity of the crop variety. Results of investigations with rice have shown that the manifestation of the effect of K would possibly be more pronounced in a truly pest-susceptible variety than in others.

4338 *Fagan, H.J.*

Effect of nitrogen and potassium on severity of *Drechslera* leaf spot and growth of coconut seedlings in sand culture

Oléagineux *40,* 5, 245–260 (1985)

Nitrogen fertilizer stimulated the extent of post-infectional development of *Drechslera incurvata* on Malayan Dwarf coconut as judged by the absence of effect on density of primary leaf spots and larger ($P<0.001$) areas of lesions produced; similarly, potassium reduced the development of the pathogen resulting in smaller ($P<0.001$) areas of lesions. The ages of leaves also influenced lesion size, with younger leaves producing larger spots ($P<0.001$) than succeeding older leaves. Nitrogen also stimulated sporulation of *D. incurvata* on coconut leaves ($P<0.01$) while potassium had the opposite effect ($P<0.001$). The effects of nitrogen resulted in increased disease severity, growth reduction and death of palms; adding potassium resulted in lower levels of disease ($P<0.001$) although application of the fertilizer alone had no effect on growth.