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Fertilizing for High Quality and Yield
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Contents

1. Importance of tobacco

Since 1492 when *Columbus* discovered tobacco in Central America, its use has spread all over the world.

Nowadays tobacco cultivation extends over an area of about 4.2 millions hectares (Table 1).

Tobacco is an important commercial crop and a valuable earner of foreign exchange in many countries. It is also a labour intensive crop which employs a large number of people on farms and in curing and processing.

Tobacco production is characterized by a particularly wide diversity in:
- Cultivars
- Soil and climatic conditions
- Plant population, topping, harvest (entire plant or leaves), curing.

It is convenient to classify tobaccos according to curing process and industrial use as follows:
- Flue-cured (Virginia) cured under controlled conditions, for cigarette and pipe
- Sun-cured a)Oriental types, for cigarette and pipe
  b) Other types for cigarette and pipe
- Light air-cured, cured under shelter (Burley), for cigarette and pipe
- Dark air-cured, cured in barn under natural conditions
  a) cigarette dark tobaccos
  b) cigar tobaccos
- Fire-cured (Kentucky), in fact smoke-cured, for cigarette, pipe and chewing.

During the last 30 years, trends have been as follows:
- Strong progress of flue-cured (Virginia) and Burley types
- An increase in sun-cured tobaccos until 1974 and a slight regression afterwards
- A decrease in dark types of tobaccos (Table 2).

Tobacco yields are still low in many regions despite emergence of new improved varieties of different types of tobacco from various research stations, combining high yielding potential and better disease resistance with desirable quality characteristics.

Quality is the most important aspect in such a crop and demands attention. Smoking quality of tobacco may undergo constant change but in any case it should have some basic physical characteristics: burning quality, colour, fineness, elasticity, taste, colour of ashes, filling power, etc.... There is still need for progress in many countries as far as quality is concerned.

Special attention will be paid in this bulletin to the nutrients which play the major roles, favourable or unfavourable, in tobacco quality, *i.e.* nitrogen, potassium and chlorine.

Table 1. Area planted, yield and production of tobacco in 1986 (FAO-1987)

	Area harvested (000 ha)	Yield (kg/ha)	Production (000 t)
Africa	*336*	*1011*	*339*
Malawi	90	789	71
Nigeria	20	575	12
South Africa	33	1182	39
Tanzania	28	429	12
Zimbabwe	61	1945	118
N-C America	*405*	*1889*	*765*
Canada	28	2250	63
Cuba	55	836	46
Mexico	48	1564	76
USA	242	2249	544
S. America	*379*	*1392*	*530*
Argentina	50	1319	66
Brazil	280	1380	386
Columbia	19	1549	29
Paraguay	14	1243	18
Asia	*2325*	*1411*	*3280*
Bangladesh	54	963	52
Burma	54	1204	65
China	959	1802	1728
India	401	1097	439
Indonesia	201	846	170
Iran	18	1222	22
Japan	48	2594	124
Korea DPR	41	1412	58
Korea REP	34	2471	84
Malaysia	15	800	12
Pakistan	48	1827	88
Philippines	57	987	56
Syria	16	1250	20
Thailand	91	934	85
Turkey	176	964	170
Viet Nam	39	972	38

Table 1. continued

	Area harvested (000 ha)	Yield (kg/ha)	Production (000 t)
Europe	*537*	*1488*	*799*
Bulgaria	107	1112	119
France	15	2422	36
Greece	100	1530	153
Italy	80	1955	156
Poland	54	1852	100
Romania	34	941	32
Spain	22	1955	43
Yugoslavia	73	1205	88
USSR	*194*	*1964*	*381*
World	**4183**	**1460**	**6109**

Table 2. Annual world production of tobacco leaf (000 tons)

	1935-39	*1955-59*	*1976*	*1984*
Flue-cured (Virginia)	615	1325	2641	2833
Light air-cured (Burley mainly)	240	315	941	1011
Dark air-cured and fire-cured	1510	1360	1361	1134
Sun-cured (oriental mainly)	635	865	1095	944
	3000	3865	6038	5922

2. Tobacco products and quality characteristics

The production comes from a number of types such as Virginia, Burley, Maryland, Kentucky, Havanna, Paraguay, etc.... Each type has its own characteristics, which may vary according to soils, fertilization, irrigation, climate and their interrelationships.

A review of the pedigrees of present varieties of *Nicotiana tabacum* suggests a limited germplasm base. Flue-cured tobacco varieties, for example, reveal a close genetic relationship. For generations breeders have recombined a common base of genetic factors, but efforts are now being made to expand this genetic base in order to improve:

1. resistance to pests,
2. tolerance to environmental stress,
3. adaptation to changes in cultural and handling practices,
4. yielding ability, and
5. consumer-quality attributes *(Keller [1976])*.

For the smoker, tobacco quality rests upon the pleasure and beneficial effects which he derives from smoking. Tobacco science was, however, greatly challenged when these benefits were questioned by health warnings against smoking. Tobacco scientists were pressed to find solutions to this problem: gradual changes were introduced over the past 30 years. Condensate and nicotine in the smoke have decreased by approximately 50% and all chemicals belonging to the particulate phase have been reduced correspondingly. Modern filters were introduced which selectively remove a number of vapour phase constituents.

Finally growers were required to certify that they did not use certain pesticides or insecticides in tobacco and residues have now essentially disappeared in good commercial grades *(Weber [1976])*.

Without entering into the organoleptic properties and the effects or sensations provoked by each type of tobacco, it is generally admitted that a satisfactory quality should include:

- a good fire holding capacity
- a satisfactory leaf coloration developing in curing
- cured leaves must generally be supple, elastic, not «chaffy» or brittle.
- ashes should be white rather than dark.

These factors determine the assigned grades, the market price, and play an important part in marketing, specially in exporting to foreign buyers. In Europe market price of Virginia grade C is about 22% of that for grade A: no other crop shows such price variation according to quality.

To the manufacturer, additional criteria will be:

- filling power
- shatter resistance
- strip yields, nicotine, sugar, mineral components
- alkalinity of water soluble ash
- total N, protein N, starch, non-volatile acids, volatile bases.

The most important final products are listed hereafter in the order of decreasing volume:

- Cigarettes: about 95% of the tobacco consumed in the world
- Smoking tobacco
- Cigars and cigarillos, tobacco leaf wrap
- Chewing tobacco, snuff (which will not be considered here).

For the consumer, there is now a marked evolution towards low tar, low nicotine cigarettes.

2.1 Soil suitability

Among the factors influencing tobacco quality, the physico-chemical characteristics of the soil play an important role.

In Sumatra, soils of volcanic origin, light, very high in organic matter are propitious to production of fine tobaccos.

In countries producing oriental tobacco types, soils considerably influence the quality: in Thrace and Macedonia, the better crops come from the hills (Yaka), where the soil is often stony, gravelly, thin and not very productive: tobacco is fairly mild and very aromatic. Tobacco grown in plains (Ova), in deeper soils, clayey, more humid, are stronger but with less aroma.

In the US, flue-cured tobacco is produced on soils which are generally light, very permeable, acid, low in organic matter and nutrients. Burley types, on the contrary, are grown in heavier soils, higher in organic matter, well aerated and drained.

Acid soils are generally best, but pH values from 5.5 to 7.6 are suitable. Soil textures may vary widely but rather light soils, with good drainage, will generally produce light tobaccos, well developed, of good colour and combustibility.

Soil defects may be compensated to a certain extent by proper fertilization.

3. Nutrient requirements of the crop

The tobacco plant grows in 60 days under warm climates and in 150 days in cold ones. In temperate regions, the vegetative cycle requires 80-110 days, with 90% of dry matter being produced during the last two months. The active growth takes place in a short period of time, during which relatively high daily absorptions are observed (Figure 1).

Compared with other crops the average daily uptake of nutrients by tobacco is relatively high, because of the short cycle (Table 4). Nutrient uptake and removal from the soil vary according to many factors: the following table gives an example of typical values found (Table 5).

Compared with these figures corresponding to air-cured tobacco for cigarettes, it appears that wrappers, for the same weight of leaves, take up much more nitrogen and potassium. (Wrappers usually contain 4% N and 6% K_2O). On the other hand flue-cured tobaccos seem to require rather less potassium than air-cured types (Figure 2).

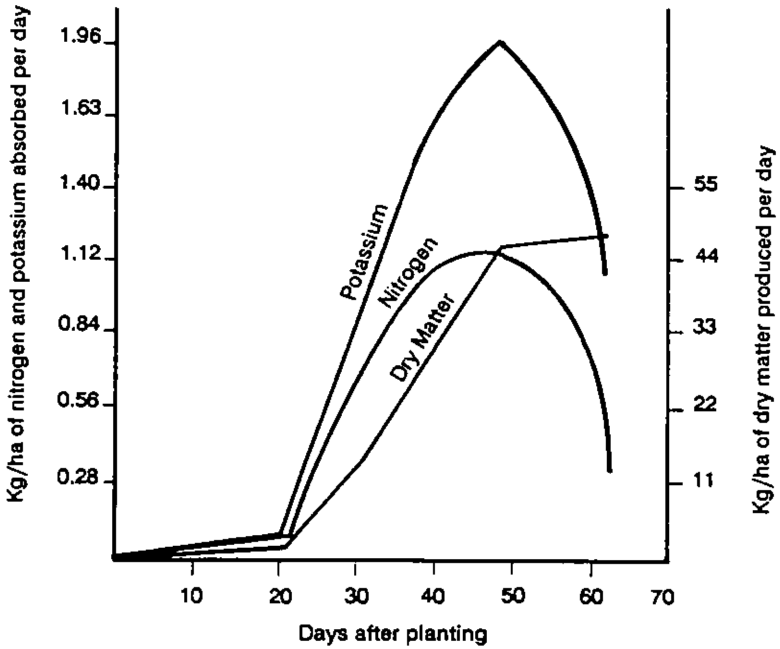

Fig. 1 Uptake rate of nutrients by flue-cured tobacco

Table 4. Daily uptake of nutrients by dark French tobacco, compared with some other crops (g/ha) *(Gisquet [1961])*

	N	P_2O_5	K_2O	CaO
Smoking tobacco	1086	235	1800	1476
Potatoes	437	203	630	137
Maize	786	194	888	333

Table 5. Nutrient uptake and removal for a production of 2000 kg dry leaves of dark tobacco (2740 kg at 27% moisture) *(Chouteau [1969])*

	Uptake	Removal	
		leaves only	stalk cutting
N	130-150	60	90
P_2O_5	30- 40	12	18
K_2O	230-240	110	160
CaO	200	140	150
MgO	25		
S	10		

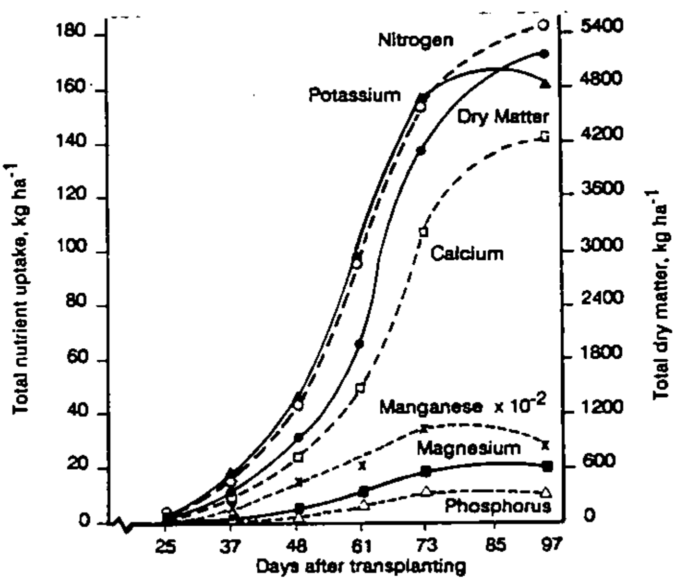

Fig. 2. Accumulation of dry matter and nutrient elements over the growing season in the aboveground plant parts of Burley tobacco *(Atkinson et al. [1977])*

3.1 Nitrogen

Usual nitrogen contents in tobacco leaves fluctuate from 2 to 5%. Deficiency symptoms appear when this content falls below 1.5%. This element is vital for protein formation, for cell multiplication and plant growth. It also plays a part in the formation of particular molecules such as chlorophyll and alkaloids (nicotine). The ease with which tobacco takes up nitrate ions may lead to luxury consumption and NO_3 accumulation in the leaves, especially in midribs. The level of N nutrition governs the protein-carbohydrate equilibrium (Figure 3).

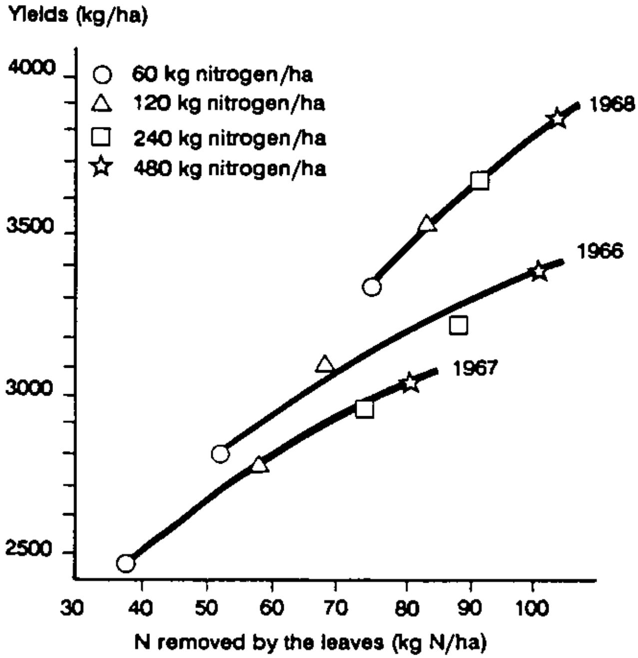

Fig. 3. Nitrogen removals per hectare in relation to nitrogen dressings and yields.

— Effect on growth and yield

Nitrogen deficiency leads to poor growth: stems and leaves remain small, with a light green colour due to low chlorophyll content. The basal leaves progressively turn to pale yellow colour and dry up. Yield is reduced.

Young tobacco plants absorb NH_4-nitrogen more easily than NO_3-nitrogen: when the N-NH_4/N-NO_3 ratio in the nutritive medium is higher than ½, the tobacco plant may show symptoms of NH_4-intoxication, due to excess accumulation of NH_4 in the sap, to physiological acidification and to the disappearance of organic salts which normally buffer the liquid content of cell vacuoles. Such NH_4 intoxication is characterized by notched leaf margins, curled upwards. The foliar tissue is thick and undulating. The color is dark green, bluish, then necrotic areas appear between the secondary ribs. In the field, nitrification of NH_4 fertilizer is generally rapid enough to supply sufficient NO_3. However intoxication symptoms have been reported on seedlings receiving high amounts of organic nitrogen (yellow patch symptom), or ammonium sulphate or urea. Tobacco plants grown on soils treated with fumigants (bromides) and fertilized with NH_4 fertilizers may easily show these symptoms. In such case, it is advised to use NO_3 fertilizers instead of NH_4.

Moderate nitrogen dressings improve plant growth: leaves are broader, their weight per unit area is reduced because they are thinner. That is why relatively high N dressings are required for producing broad and thin leaves for cigar production.

In the case of dark air-cured tobaccos, excess N dressings, over 400 kg/ha N, may slow down the start of growth, particularly if the soil is dry. Normally, the more nitrogen applied, the greener the plants are, with delayed maturation. Nitrogen excess may also increase losses from fungal diseases, such as *Alternaria longipes*. In experiments on dark air-

Table 6. Effect of N fertilizer on yield (kg/ha dry leaves). *Bergerac Tobacco Institute (Chouteau [1969])*

Nitric nitrogen rates* (kg/ha)	60	120	240	480
1966	2799 (100)	3097 (111)	3208 (115)	3384 (121)
1967	2459 (100)	2784 (113)	2951 (120)	3038 (124)
1968	3332 (100)	3519 (106)	3664 (110)	3840 (115)
Average 3 years	2863 (100)	3133 (110)	3274 (115)	3421 (120)

* In addition to 40 t/ha manure

cured tobacco (Table 6) corresponding to 1 kg nitrogen were as follows:

From 60 to 120 kg/ha N: 4.5 kg tobacco/kg N
From 120 to 240 kg/ha N: 1.2 kg tobacco/kg N
From 240 to 480 kg/ha N: 0.6 kg tobacco/kg N

– Effect on quality

a) Water content at harvesting
Nitrogen fertilization increases the water content of green leaves. The fineness of dry tissues resulting from moderate N dressings is probably related to the high hydration of the green leaves.

b) Colour
The colour of tobacco after curing is clearly influenced by nitrogen rates, specially for flue-cured tobaccos. Under any curing method, N-deficient leaves are pale, with a colour which is not uniform, showing green-slashes called «bassara» for oriental tobaccos. In general, moderate nitrogen applications can improve the quality, especially by ameliorating the development of colour during the curing process.

This produces warmer and more uniform colours in air-cured tobaccos. However when the N nutrition is reinforced, the chlorophyll will not disappear so easily and cured leaves will remain green or brownish with a tendency to darken when tobacco is fermented. This effect may be accentuated by the NH_4 form.

c) Burning quality
Since *Garner's* work [1934] it is generally admitted that combustibility is lowered when N nutrition is increased. However in some cases it was possible to observe a favorable effect of NO_3 upon the combustibility, resulting from a better K accumulation and a reduced absorption of SO_4 and especially Cl. This favorable effect of NO_3 is particularly marked when the nutritive medium is high in chlorides (Tables 7 and 8).

Table 7. Effect of NO_3-N level on combustibility in the presence of high amounts of chlorides. (Pot experiment)

Treatments		Contents in leaves me/100 g DM		Combustibility seconds
N-NO_3 g/plant	Cl g/plant	K	Cl	
4	4	140	83	1.0
8	4	173	50	7.0

Table 8. Effect of N-NO_3 dressing on combustibility of dark tobacco (seconds) in field trials low in chloride

N rates	60	120	240	480
Average 3 years, combustibility	4.5	4.7	5.5	5.2

d) Taste

Nitrogen is considered to be the element which has the greatest influence, excess rates leading to aggressive taste and nitrogen deficiencies to a tasteless smoke. This is related to the equilibrium between sugar and protein.

— Forms of nitrogen

Urea is not commonly used for tobacco because of the unpredictable availability of its nitrogen content to the crop.

Under favourable conditions ammonium is rapidly transformed into nitrate by activity of microorganisms but where this conversion is slow, tobacco with its high demand for nutrients may take up much ammonium with harmful effects.

Finally, it seems that ammonium nitrate is the most advisable form in most cases, other nitrates fitting also, specially for side dressing. However, in soils with pH exceeding 7.5, ammonium nitrogen is suitable.

It is frequently advised to apply not more than 50% of the total N as basal dressing and the remaining as side dressing later on. The first side dressing can sometimes be applied as ammonium nitrate so long as this is not more than 5 weeks after planting. All subsequent side dressing should be in the form of Ca or K nitrate, depending on the K status of the soil.

3.2 Phosphorus

Usual phosphorus contents in tobacco leaves range from 0.4 to 0.9% P_2O_5. This element accumulates principally in young tissues and the P content in the leaf declines as it ages (Figure 4). Field trials have shown that the P status of the soil has little influence upon the P content of mature leaves, unlike potassium and chlorine.

The response of tobacco to phosphorus applications depends on soil temperature, the absorption being significantly reduced when this temperature is reduced from 35 ° to 10 °C: for a given P concentration in the soil solution, a better response to added P may be observed at 14 °C than at 21 °C. This explains why several studies have shown that P can be the most important limiting factor in cold soils.

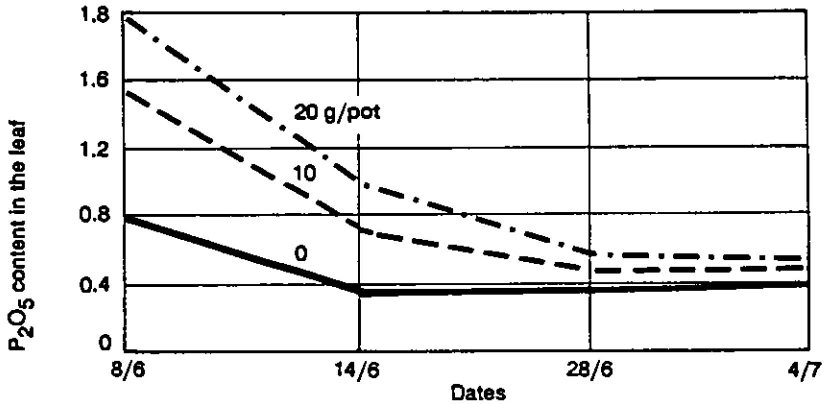

Fig. 4. Pot experiment: influence of 3 phosphorus rates (superphosphate) on P_2O_5 content in the leaf, and evolution with the age of the tobacco plant *(Chouteau [1969])*

Table 9. Influence of P_2O_5 on root development and nicotine content *(Tob. Inst. Bergerac/France; Chouteau [1969])*

P_2O_5 application		Soils with decreasing amounts of available P_2O_5				
		P5	P4	P3	P2	P1
0	Root Wt / Leaf Wt	0.67	0.66	0.55	0.36	0.42
	Nicotine % DM in leaf	1.60	0.87	0.84	0.79	0.87
10 g superphosphate per plant	Root Wt / Leaf Wt	0.76	0.75	0.60	0.55	0.60
	Nicotine % DM in leaf	1.63	2.14	1.75	1.70	1.92
20 g superphosphate per plant	Root Wt / Leaf Wt	0.78	0.86	0.76	0.69	0.61
	Nicotine % DM in leaf	1.85	2.01	1.65	1.58	1.74

The pH of the soil may reduce the P nutrition, either at levels below pH 4 or over 7, as a result of its insolubilization. The optimum pH range for good P availability extends between pH 5 and 6.

– Effect on growth and yield

Phosphorus deficiency results in very slow growth, specially in the young stage. Plants are thin, leaves are narrow with a dark green colour, even bluish. Frequently the lower leaves exhibit many brown spots.

Soils high in available P provide rapid and vigourous growth of the young plants and particularly of their root system. Blooming and maturity are earlier.

Plants well fed with P, with accelerated growth and maturation, should then suffer from temporary droughts because they would be less able to recover normal growth: this has sometimes been mentioned for Burley varieties with subsequent negative effects on quality.

– Effect on quality

Most experiments have shown that, in soils low in P, phosphorus dressings could improve the quality of cured leaves through better maturation in the field and improved coloring in curing. There was no effect on combustibility. Some experiments have shown that excessive P dressings, associated with low nitrogen applications, could induce green slashes on cured leaves and «bassara» on oriental varieties.

Improving the phosphorus nutrition may have an indirect effect on nicotine content through earlier topping (Table 9).

P deficiency, like many other mineral deficiencies, may increase amino-acid content of the leaves. When P is adequate, the total N in the mature leaves will generally decrease.

Adequate phosphate is essential not only to promote the uniform ripening of the leaf and for its favourable influence on the formation of carbohydrates, but as shown in Zimbabwe, the uptake of potassium is largely dependent on the supply of phosphate and *vice versa (Lampard [1980])*.

– Forms of phosphate

All water soluble forms of phosphates are equally effective and advisable on tobacco. Basic slags, when available, are suitable in acid soils.

3.3 Potassium

Usual potassium concentrations in tobacco leaves range from 2 to 8% K_2O, sometimes reaching 10%. Deficiency symptoms appear below 3% K_2O and are severe at 2%. The K_2O content decreases in the course of the growing cycle (Figure 5 and Table 10).

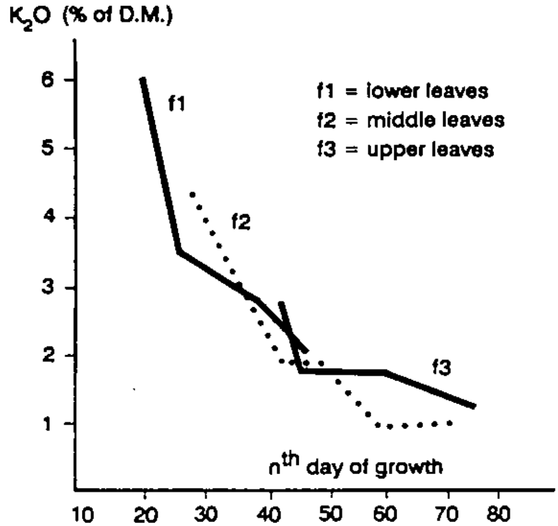

Fig. 5. Changes in the K_2O content of the parenchyma during the growth

Table 10. Example of variation in K_2O concentration in middle leaves

date of sampling	7/7	17/7	27/7	6/8	14/8	29/8
K_2O % DM	5.7	4.5	3.9	3.6	3.6	3.7

At a given time, when the potassium nutrition of the plant is adequate, the K concentrations of upper, median and lower leaves are more or less the same. When harvesting is at intervals, the lower leaves picked earlier are higher in K than the upper leaves harvested later. In the case of air-cured tobacco, with an average K_2O content of 5.5% K_2O, 2000 kg of dry leaves (2740 kg at 27%) remove 110 kg K_2O in a leaf crop and 160 kg in a stalk cutting crop. The distribution of K in the leaf is not uniform, the midribs contain 2 to 3 times more K than the parenchyma.

In the last growth stage, the leaf K content is markedly affected by the available K status of the soil. Studies carried out at the *Bergerac Institute*, have illustrated the relationship between the exchangeable K of light alluvial soils (<13% clay) and the K_2O content of tobacco leaves grown on these soils (Figure 6). In soils higher in clay, higher exchangeable K would be required to get the same level of K in the leaves: this is true for all crops. Interpretation of soil analysis should then take into account both:

- exchangeable K (or K_2O) and clay content

or better

- exchangeable K (or K_2O) and soil C.E.C. (Figure 7).

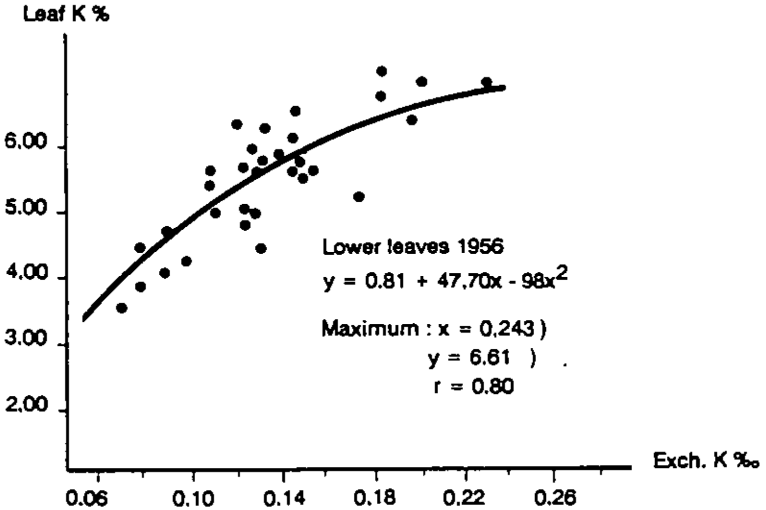

Fig. 6. Relation between exchangeable K content of soil and K content of lower leaves at maturity

Good K nutrition allows the plant to better resist temporary droughts and certain fungus attacks *(Gisquet [1961])*.

Allington [1976] and *Spencer [1935]* have demonstrated a positive effect of potassium on resistance to mosaic virus infection, with parasite development or damage decreased by 17 to 78%. *Riley [1949]* has also shown better resistance to the brown spot disease, caused by *Alternaria longipes*, with good K nutrition.

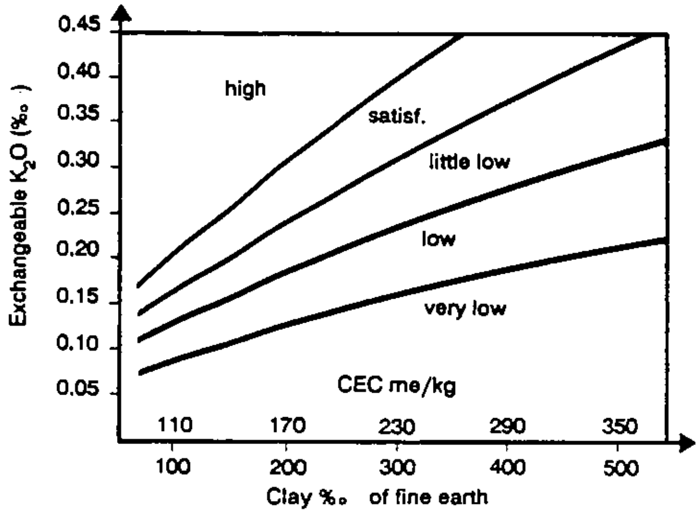

Fig. 7. Graph used in soil-K interpretation in France, based upon crop responses to applied potassium in field experiments. *(Quémener [1985])*

— Potassic nutrition and chemical composition of the leaf

a) water content of the leaf on the living plant.

Potassium enrichment of the green leaf is associated with an increase of its water content. This may explain the better resistance to leaf scald when leaves are well supplied with K. This turgor of green leaves has a beneficial effect on their quality after curing.

b) Acid - base equilibrium (K, Ca, Mg, organic acids)

Leaf K enrichment is associated with a slight decrease in combined organic acid content (total alkalinity of ashes) due to 2 effects:

1. penetration into the leaf of the anion accompanying K and which is little metabolizable (sulphate or chloride).
2. decrease in the Ca and Mg contents, which does not counterbalance in equivalents the accumulation of K.

The competition, at root level, or the compensation process on the acid-base equilibrium, between K on the one hand, and Mg, Ca, Na on the other hand, have been demonstrated since a long time on tobacco plants. In practice, the most important is K-Ca competition, which leads some agronomists to advice higher K dressings on soils rich in Ca.

The alkalinity of water-soluble ash, an indicator of fire-holding capacity (AH), *i.e.* organic acids bound to potassium, is increased by potassic manuring, the more so as the anion supplied with K is more metabolized (NO_3>SO_4>Cl). In general AH ≃[K + Na] − [Cl + SO_4] where K, Na, Cl and SO_4 are the concentrations of each element in the leaf. Tables 11 and 12 show examples of this, with analysis of the water-soluble fraction of tobacco ash from K fertilizer experiments, in pots and in the field.

Table 11. Experiment with potassium nitrate in pots. Acid-base equilibrium of water soluble ash fraction (values in me/100 g DM)

Treatments		Acid-base equilibrium of the watersoluble fraction of leaf ash						
Cl (g/plant)	K NO_3 (N g/plant)	K	Ca	Mg	Cl	K-Cl	AH	Combustibility (seconds)
	3	107	4	4	97	10	4	1.1
5	6	149	0	2	94	55	46	2.1
	9	183	0	0	64	119	110	6.5

Table 12. Experiment with potassium sulphate in the field

Potassium sulphate K_2O kg/ha	Average chemical composition of all leaves (me/100 g DM)			
	K	Cl	K-Cl	AH
0	96	24	72	45
400	122	30	92	61
800	134	38	96	63

c) Other constituents

An accumulation of nitrogenous compounds particularly in soluble form, is observed in the leaves of K deficient plants. Several authors have reported that the content of reducing sugars in the leaf increased with K.

— Effect on growth and yield

Although K requirements of tobacco are generally high, the precise physiological role of this element has not been well understood for a long time. It is found mainly in ionic form in the vacuole. For this reason, it plays an essential role in the acids/bases equilibrium inside the vacuole, and in the regulation of the osmotic pressure. A very small fraction only is in a bonded form in the cytoplasm. Potassium is known to activate a number of enzyme systems.

K deficiency symptoms are very typical. First the leaves exhibit a dark green colour, then yellowish spots appear at the top and later on the margins of the leaves, extending progressively to the midrib. These marginal discoloured areas of the leaf having a slower growth than the central part, a downward curling appears at the tip and margins of the leaf. Simultaneously the leaf shows a crinkled appearance. The yellowish spots then die. In severe cases, the leaf may dry up completely. If the deficiency occurs early in growth, the symptoms first affect the lower leaves. When the symptoms appear later, the upper leaves are more severely affected.

It is sometimes difficult to distinguish the mottling of the leaf which is characteristic of early maturity from the symptoms of mild K deficiency, though in the latter case the yellow spots always show a marginal area of dark blue green colour.

Deficiency symptoms often occur, specially after heavy rains on sandy soils, in soils low in exchangeable K, and/or after exhausting crops such as grass etc.... They are aggravated by nutrient unbalances, particularly by excessive S or N supplies. *Lovett [1959]* found that increasing levels of K increased leaf area and also weight per unit area.

Increasing rates of potassium often have a limited effect on yield, however significant responses of tobacco to potassium application, in terms of yield, have been reported in some cases, even though quality effects are of major importance. An example is given from India, on flue-cured Virginia tobacco grown in Andhra Pradesh State on one heavy and three light soils with «high» initial status of available K, 10 replications *(Krishnamurthy et al., [1984]* [Figure 8]).

Except for the soil S_3, the response to increasing rates of K (applied every year) was more or less linear, with yield increases of 31-51% at the highest K level. There was no difference between the heavy soil and the light soils with respect to the effect of K application on tobacco yield, except that the yield of cured leaf from the no K treatment and at the highest K level was slightly higher on the heavy black soil.

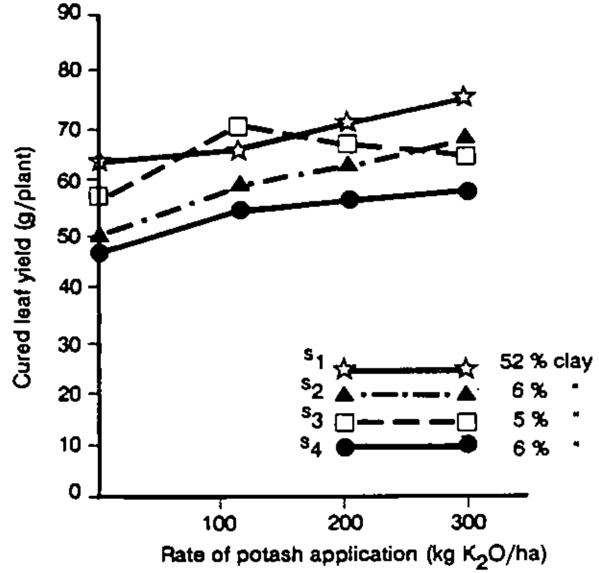

Fig. 8. Response of flue-cured tobacco plants to potash application in a 3 years pot experiment at the *Central Tobacco Research Institute*, Rajahmundry, India *(Krishnamurthy [1984])*

Due to the rapid depletion of available K in the light soils without K application leaf K contents were very low in the 2nd and 3rd crop season. With increased K supply, foliar K values rose to the desirable level of 3-4%. In contrast to this, on the heavy black soil the K content in the leaves was not so low at K_0 but it did not rise very much with increasing K application (Table 13 and Figure 9). This illustrates the higher K buffer power of the black heavy vertisol S_1. At the highest rate of K application the uptake of potassium on the heavy soils was only ⅔ of the uptake on the light soils. It can be concluded that higher rates of K would have been useful to increase the yield further and eventually lead to a higher leaf-K content of flue-cured Virginia (FCV) tobacco grown on the heavy soil.

Sims [1978] mentioned yield responses to K applications up to 675 kg/ha K_2O, but that most often 70-145 kg/ha on medium and high testing soils and 145-270 kg/ha K_2O on low testing soils is sufficient for maximum yield. However, up to double these rates are often recommended to replace K removed by the crop and to maintain or improve quality.

Table 13. K content of the leaf, mean of 1978/79 and 1979/80 (dry matter %) *(Krishnamurthy [1984])*

Treatment	K_0	K_{100}	K_{200}	K_{300}
S_1 (clay)	1.48	1.83	2.20	2.20
S_2 (sand)	0.78	2.19	2.01	3.88
S_3 (sand)	0.63	1.95	2.25	3.78
S_4 (sand)	0.53	2.60	2.87	3.88

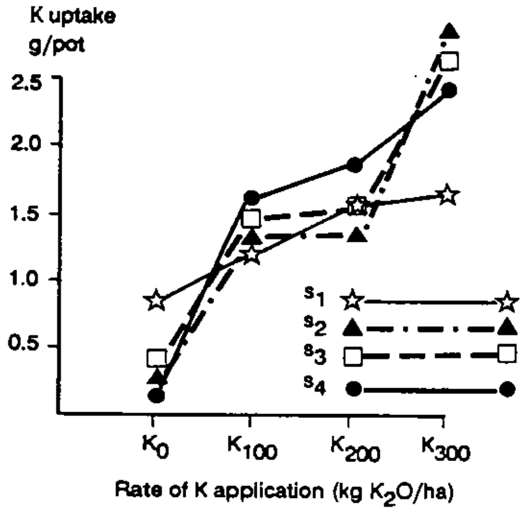

Fig. 9. K uptake by tobacco leaves (1978/79-1979/80). *(Krishnamrthy [1984])*

— Effect on quality

The market value of cured leaves is dependent mostly on quality. Potassium is an important factor of quality for tobacco. A high K content in cured flue-cured tobacco has frequently been used as one measure of quality, and relatively few soils on which this crop is grown are capable of consistently producing the quality or the yield desired without fertilizer potassium *(Hawks [1983])*.

The potassium dressings actually used in the culture of tobacco may exceed 2 to 3 times that amount required for maximum yield. This amount is claimed by some to be justified on the basis of the widely held opinion that improvement in quality continues to occur from rates of K beyond those required for maximum yield.

a) Physical appearance of the cured leaf.

Increased applications of potassium generally produce flue-cured Virginia tobacco which is more elastic and pliable, and has a deeper orange colour. With poor K nutrition the colour of air-cured tobacco does not develop so well in the curing barn, the leaves being distorted and mottled with a persistent greenish colour. Tobaccos insufficiently supplied with K are «chaffy» and brittle after curing. *Lovett [1959]* has shown that leaves grown at high potassium level dried out bright yellow, whereas at lower potassium level the leaves rapidly turn brown when the curing temperature was raised to 49 °C. Potassium manuring also confers fineness and elasticity on tobacco leaves for cigar wrappers.

b) Nicotine and sugar

Some authors have reported that potassium applications reduced nicotine and increased sugar concentration *(Mac Cants [1960], Liang Deyin [1983])* (Table 14).

Table 14. Effect of K fertilizer on composition of tobacco *(Tobacco Research Institute. Chinese Academy of Agricultural Science [1972]) (Liang Deyin [1983])*

Treatment	Reducing sugar %	Total sugar %	Total N %	Nicotine %	Smoke value
Control	12.26	15.20	2.63	2.20	1.06
K 60 kg/ha	13.87	16.81	2.34	2.12	1.36
K 120 kg/ha	14.62	18.81	2.06	1.95	1.75

c) Combustibility

There is substantial evidence to show that there is a positive correlation between the K content of the cured leaf and the rate of burn and the fire holding capacity. This has been confirmed by a survey carried out by *Chouteau* on French tobaccos (Figures 10 and 11).

Cuban studies of the influence of K_2SO_4 on tobacco quality show that it improved combustibility by increasing glowing time from 12s for zero K treatment to 28s for the intermediate rate and 104s for the highest K treatment *(Usherwood [1985]). Saragoni (1982)* has shown that a sufficient fire holding capacity for cigarette tobacco (6-7s) could be obtained by growers in La Réunion, in brown tobacco, by avoiding the use of chlorides and when the following condition is satisfied:

$$\text{leaf K} - \text{leaf Mg} + \text{Cl} > 0$$

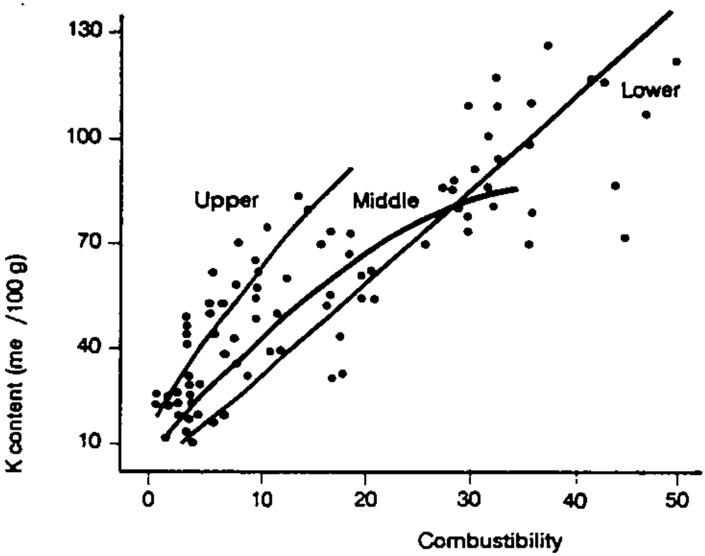

Fig. 10. Pot. trial. Relation between leaf K content and combustibility *(Chouteau [1969])*

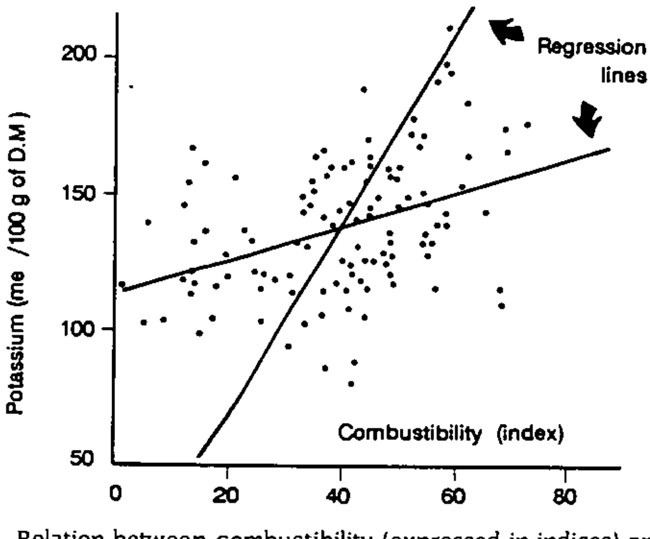

Fig. 11. Relation between combustibility (expressed in indices) and K content of tobacco leaves from different areas of production in France (r=0.451) *(Chouteau [1969])*

As seen in the following, chlorine is highly detrimental to the burning quality of tobacco and may obliterate the favourable effect of potassium. Therefore muriate (or potassium chloride) should always be prohibited for tobacco, potassium sulphate being the most suitable form.

3.4 Chlorine

Leaf Cl content may reach 10% of the dry matter, and 5 to 10 times more in the midrib than in the parenchyma. In fact, it is obvious that a too high chloride content is one of the essential causes of the unusual quantity of lower grade tobacco which appeared on the market *(Cants [1965])*.

The absence of chlorides in the nutritive medium does not lead to any deficiency symptom. However it has been shown that a moderate chloride supply may have a favourable effect on leaf development. However excessive absorption of Cl by the tobacco plant leads to leaf malformation, leaf thickening and curling upwards of leaf margins. Chloride ions are readily absorbed by tobacco plants and the Cl content increases as the supply to the root is increased (Figure 12). There is competition between nitrates and chlorides in the uptake process. Cl also restrains the absorption of sulphur. The most spectacular effect of chlorides is their action on the alkalinity of soluble ash (AH), *i.e.* essentially on the potassium carbonates produced during the combustion process from the organic acids associated with K.

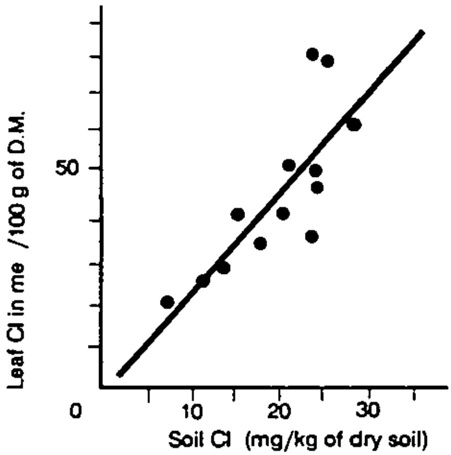

Fig. 12. Example of relationship between Cl content of soil early in July and Cl content of middle leaves at harvest *(Chouteau [1969])*

More precisely when leaf K content is variable, the alkalinity of soluble ash is proportional to the difference between the K^+ and Cl^- contents of the leaf, since Cl^- takes the place of the organic anion in the ionic equilibrium $(K^+)/(Cl^-$, organic acids).

For French tobacco, the following relation was found (expressing K and Cl contents of the leaf as well as the AH value in me).

$$AH \cong 0.92\ (K - Cl) - 23$$

The diagram below shows the relationship between AH and K-Cl in French conditions (Figure 13).

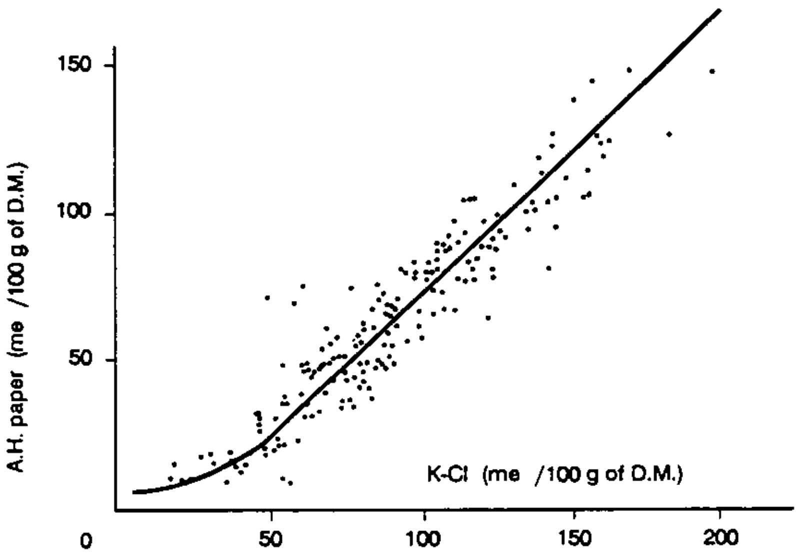

Fig. 13. Relationship between alkalinity of soluble ash (AH) and K-Cl *(Chouteau [1969])*

Myhre [1956] indicated that to ensure good combustibility the K content must be at least as high as the combined content of N, Cl and S.

Excess of Cl in the leaf disturbs the metabolism of sugars, whereas starch accumulates. In general, dry conditions favour chlorine uptake.

– Effects of Cl on the cured leaf

Very moderate amounts of chloride, up to 0.5% DM, may improve tobacco quality: the leaves on the stalk are more turgescent, have a higher water content and consequently are larger and finer after curing. But chlorinated tobaccos generally have a dull and pale colour. The midribs are white or greyish and soft, their colour is in sharp contrast with the parenchyma. These tobaccos are flabby, oily, spongy and cold to the touch. The hygroscopicity of tobaccos is greatly increased by Cl. The moisture which they hold makes them soft and difficult to store, and mould development is increased.

Above all, many experiments have shown that the accumulation of chlorides in the leaf decreases the combustibility. This is particularly perceptible when the Cl content exceeds 1%. When it reaches 2% the combustibility is very low (Figure 14).

Excess of Cl is very unfavourable. That is why *any chlorine supply should be carefully avoided*, specially through fertilization. The more so since farm manure may contain a substantial amount of this element.

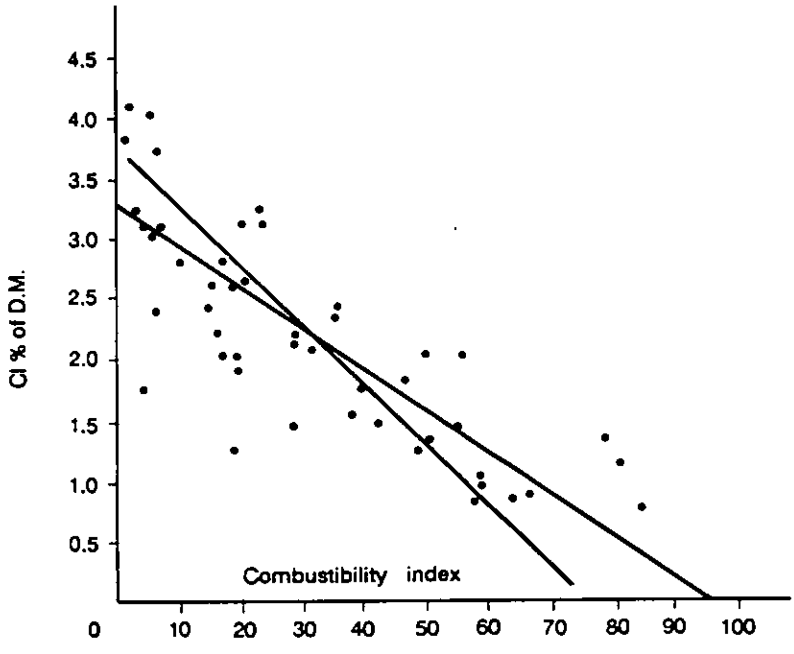

Fig. 14. Relation between combustibility and Cl content of 50 harvested crops bought in 1965 at the buying center of Bergerac. *(Chouteau [1969])*

– Sources of chlorine in the farm

a) Cl in the soil

Most soils contain some Cl which may result from muriate applications for preceding crops of the rotation. Many tobacco growers try to avoid this by using potassium sulphate on these preceding crops.

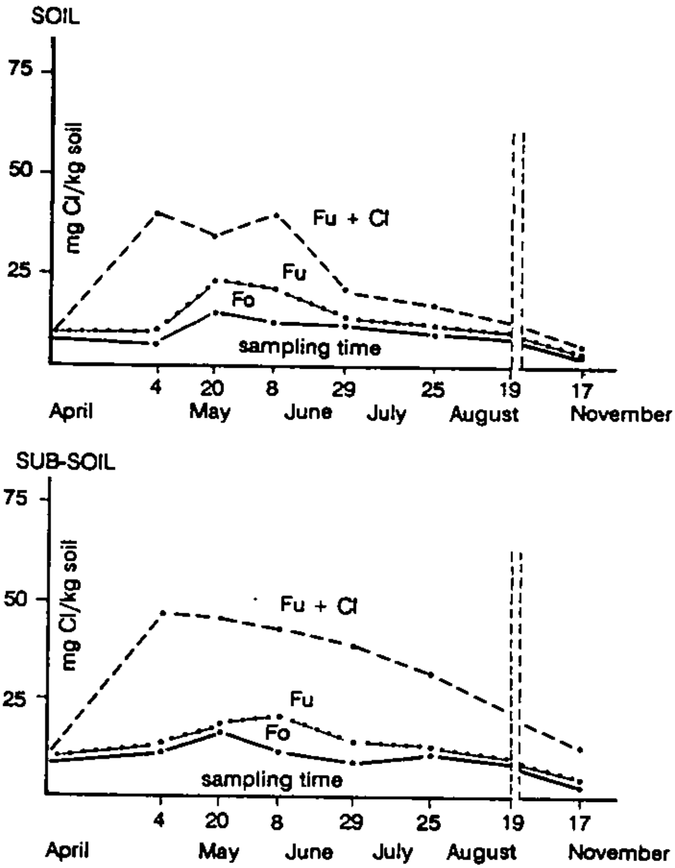

Fig. 15. Examples of variation of Cl contents of a soil and subsoil after application of organic manures: Fu + Cl = farmyard manure with high Cl content; Fu = farmyard manure with a little chloride; Fo = Composted household refuse.

In summer, Cl may rise very rapidly from the subsoil. It has been observed generally that tobaccos growing during dry summers were relatively rich in Cl and of low combustibility.

Seasonal variations of soil chloride contents
It has been shown that after winter, just a little chlorine is found in the ploughed layer of light and well drained soils, while in soils with an unfavourable texture or structure, in soils with a marked plough-pan and in areas where for topographic reasons water concentrates, chlorine tends to persist during winter. Figure 15 shows the variation of Cl contents of an alluvial soil, rather well drained on the surface.

b) Farmyard manure
It has been known for a long time that the use of farmyard manure for the fertilization of air-cured tobacco leads to an increase of the leaf Cl content. This is the reason why American growers are advised to moderate farmyard manure dressings on Burley tobacco fields. It is equally certain that the Cl contained in some French tobaccos comes from farmyard manure.

The Cl content of fresh farmyard manure is very variable. This may be observed when considering Figure 16 which shows the scattering of Cl contents for 480 samples from several regions of France. It is generally estimated that 1 ton farmyard manure supplies about 2 kg of Cl. Sheep manures are generally richer in chlorides than cattle manures. Poultry manures are rich in Cl (3.9‰). The effect of farmyard manure on Cl content of the leaves depends on its characteristics, date of application and physical conditions of the soil, mainly drainage.

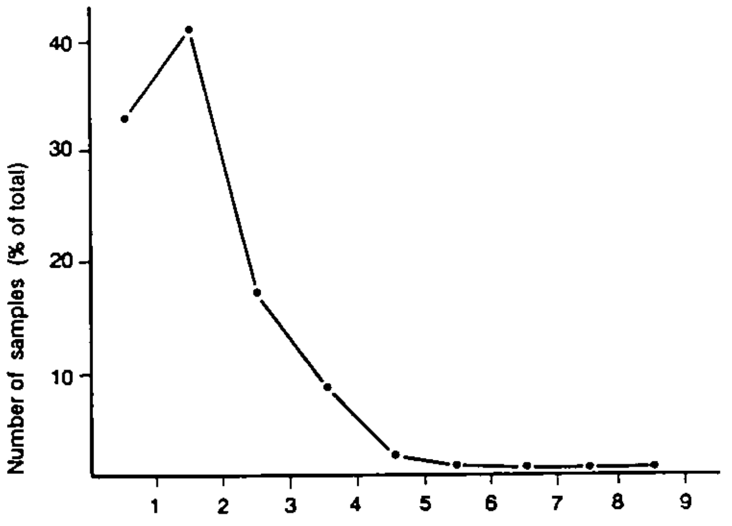

Fig. 16. Classes of Cl contents (‰ of farmyard manure in bulk) *(Chouteau [1969])*

c) Irrigation water

Irrigation waters may bring substantial amounts of Cl. In Australia, it is assumed that waters containing more than 40 ppm are unsuitable for tobacco. Some experts give a limit at 25 ppm Cl *(Trai [1980])*. Table 15 shows the influence of certain irrigation waters on the Cl content and on the combustibility of the tobacco leaf, in experiments carried out in the region of Bergerac, France.

Table 15. Trials with various irrigation waters in Bergerac region (France) *(Chouteau [1969])*

Trial	Cl content in water (ppm)	Cl content in leaves %	Combustibility (seconds)
A	10	0.75	5.0
	150	2.49	1.6
B	10	1.85	1.7
	140	4.44	0.8
C	10	1.67	2.7
	140	3.91	0.6

d) Fertilizers

Tobacco growers should understand that potassium chloride and any compound fertilizer manufactured with chloride must be prohibited for tobacco. Special formulas based on potassium sulphate are available for this crop.

Table 16. Comparison of potash forms *Llanos Company [1984])*

Measurement	Sulphate	Chloride
Combustibility	13.28	7.43
Filling power	34.82	36.35
Chlorine	0.94	2.37
Ash	24.89	25.34
Total N	4.08	3.47
Total volatile bases (TVB)	0.690	0.676
Nicotine	1.17	1.00
Sulphur	0.32	0.29
Protein N	1.S4	1.82
Potassium	5.98	5.58
Calcium	7.18	7.71
Magnesium	1.22	1.37
pH	6.23	6.25

Experiments in Spain, including physico-chemical analysis of cured leaves from individual plots under sulphate and muriate treatments, gave the results indicated in Table 16. Standard potassium sulphate may contain 2-3% Cl, which added to other possible sources of Cl from manures, irrigation, etc...., is quite sufficient to provide the very small amount of chlorine required. In areas where high Cl contents in the soil or in irrigation water pose a threat (e.g. Pakistan), it is essential to use a «low-chlorine» sulphate with less than 1% or even 0.5% Cl.

Potassium nitrate is also a suitable form although its use is rather restricted.

3.5 Sulphur

Usual S content in the leaf ranges from 0.3 to 0.4%. Symptoms of S deficiency appear when the S content falls below 0.1%.

No matter how much sulphate the plant is given, the organic S content of the leaf increases very little and never exceeds 7 me per 100 g DM. However, S is stored in form of water soluble sulphates, mostly as potassium sulphate.

The sulphate level in the nutritive medium affects the total S content of the leaves but the relationship between soil S and plant S is much less clear than that between soil Cl and plant Cl, as the sulphate ion is absorbed by plants at a low rate.

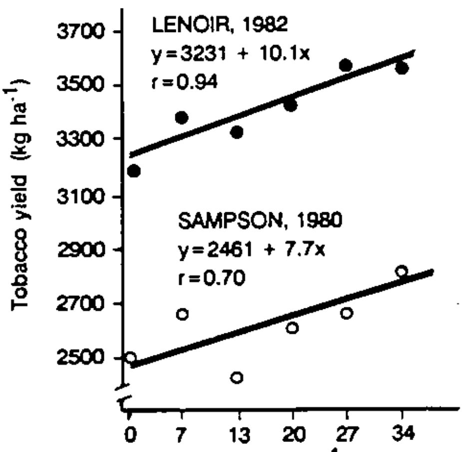

Fig. 17. Effect of sulphur rate on tobacco yield at Lenoir and Sampson country, N. Carolina USA *(Smith [1987])*

Smith [1987] has observed sulphur deficiency symptoms on flue-cured tobacco grown on some sandy coastal plain soils in North Carolina. Field experiments were conducted in 1980, 81 and 82 over a range of typical soils, with six rates of S. Yield response to S application was quite variable, but significant linear yield responses were observed in deep sandy soils at two out of four locations, with argillic horizons > 4.5 m deep, and soil SO_4^{2-}-S concentrations of 2-5 g m^{-3} in the upper 0.45 m (Figure 17).

The physical quality of the cured leaf was not affected by S rate. Results indicate that tobacco grown on soils with shallow horizons (< 0.30 m) would not respond to fertilizer S due to adequate SO_4^{2-}-S concentrations within the rooting zone (Figure 17).

— Functions of S

Like nitrogen, sulphur, though quantitatively less important, is a constituent of some proteins. An important fraction of the plant S is found as free sulphates and as such can play a function similar to that of Cl in the acid/base equilibrium.

Symptoms of S deficiency are very similar to those induced by N starvation: a pale green or even yellow colour of the leaves. The chlorosis is uniform on the blade and is particularly striking on young leaves. Generally, deficient leaves do not wither. Such a deficiency occurs rarely in the field. Excessive uptake of sulphate may be more frequent. In this case, plants show a dark green bluish colour.

— Effects on yield and quality

Specific effects of the S ion on yields have hardly been noted. However it is generally admitted, mainly for flue-cured tobacco, that a slight S deficiency is beneficial to the quality of the cured leaves, as it would help to produce light yellow colours. Excessive sulphate accumulation in the leaves would decrease the proportion of potassium linked to organic acids, lowering the burning quality (Table 17).

Table 17. Chemical analysis of tobacco grown in the district of Aiguillon (S-W France) show S contents that may be somewhat high *(Chouteau [1969])*

S leaf blade % DM	0.59	0.67	0.78	0.93
Burning quality	satisfactory	fair	poor	bad

However this has not always been found in experiments for at least two reasons:

1. sulphur affects burning quality only if it is stored in the leaf as free sulphate,
2. a higher level of S in the growing medium has relatively little influence on the S content of the leaves.

In practice, there is little evidence of this negative effect on combustibility.

3.6 Magnesium and calcium

Normal concentrations in leaf dry matter are 0.5 to 2% MgO and 2.5 to 5% CaO.

Mg deficiency symptoms may appear where MgO content falls below 0.4% and becomes severe at 0.2%. This element is an essential constituent of chlorophyll and it is also a catalytic agent in a number of enzyme processes. Leaves low in Mg exhibit chlorotic symptoms, starting at the tip and margins, then moving to the center of the blade but leaving the ribs green. Chlorosis always starts on older leaves and progresses to the top of the plant. Mg deficiency results in accumulation of non-protein nitrogen, a decrease in leaf sugars, and dull colour of the cured leaf.

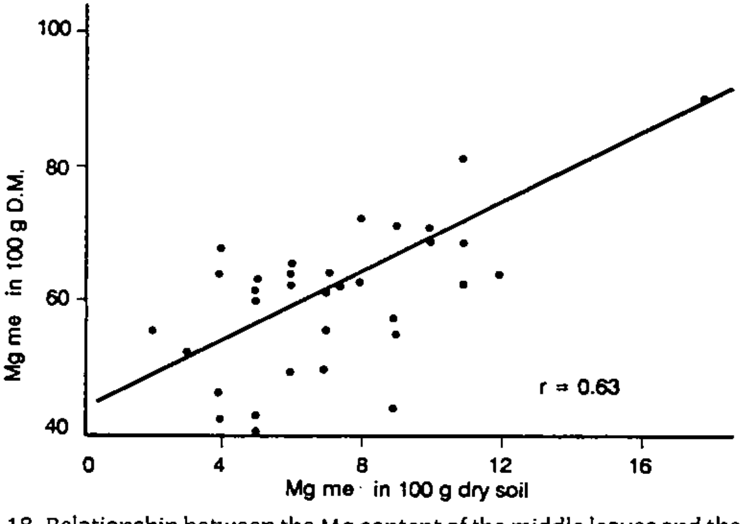

Fig. 18. Relationship between the Mg content of the middle leaves and the exch. Mg of light soils (10 to 13% clay) *(Chouteau [1969])*

Calcium is a constituent of the middle lamella. Like potassium, it neutralizes the organic acids. Soil Ca content affects the Ca content of the leaves little.

There is marked antagonism in the uptake of the 3 cations K, Mg and Ca, enrichment of the medium in one of them tending to reduce the absorption of the others. This is particularly true for K-Mg (Figure 19).

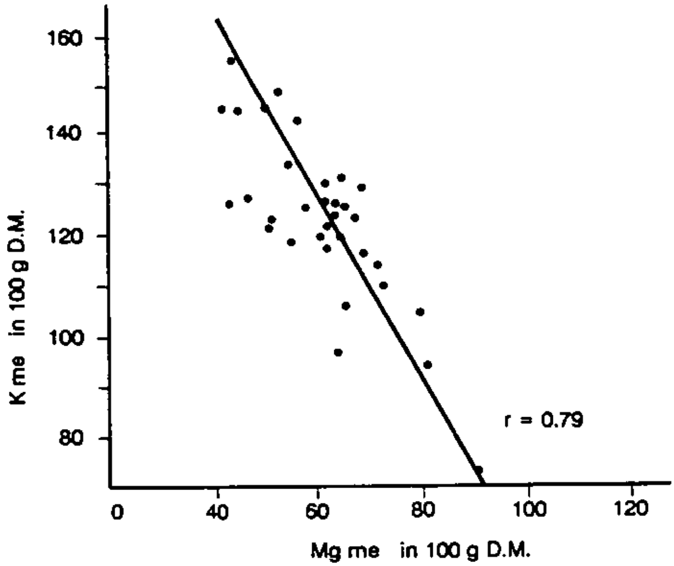

Fig. 19. Relationship between leaf K and leaf Mg in mature middle leaves *(Chouteau [1969])*

Several authors have found that higher Mg contents in the leaves were associated with a decrease in combustibility, but in this matter it is difficult to dissociate the effect of Mg-excess from the effects of a K-deficiency.

In fact Mg deficiency is not common on tobacco. It has been observed mainly in sandy soils («sands drown disease») and in rainy years. This is explained by the leaching of Mg under such conditions. In this case it is most advisable to associate Mg with K in fertilizer treatment.

As shown in Table 18, the Ca content of the leaf increases over the growing period. Despite the simultaneous decrease in K content, the sum of the cations and of the organic acids bonded to them increases.

Table 18. Anion/cation balance in middle leaves during the last 2 months of growth, me/100 g DM *(Chouteau [1969])*

Sampling dates	K	Ca	Mg	Sum of cations	Alkalinity of ash
7 July	122	56	21	199	138
17 July	96	80	21	197	136
27 July	83	139	17	239	200
6 August	77	145	17	239	195
14 August	77	136	21	234	189
29 August	80	154	19	253	214

3.7 Micronutrients

Four microelements may be responsible for disorders in tobacco growth: Boron, zinc, copper and manganese.

— *Boron* plays a role in lignin formation and in the growth of meristematic tissues. Normal B content is 10-40 ppm. Deficiency symptoms appear when this content falls below 15 ppm in the terminal bud. Disorders: the young leaves are discoloured, crinkle and cockle following death of vascular tissues; the terminal bud may disappear inducing the development of axillary buds which die in their turn. The tobacco plant gets a bushy shape. The nicotine content may be multiplied fourfold by B deficiency. Excess of boron provokes scorching of leaf margins.
In some countries, for instance in flue-cured production areas of the U.S.A, borax applications (0.3-0.5 kg/ha B) are recommended.

- *Zinc:* Normal concentrations in the leaf range from 20 to 80 ppm. «Zinc disease» occurs mainly in rainy summers, showing necrotic spots looking like certain bacterial diseases *(McMurtrey [1941])*.

- *Copper* content in leaves usually is about 30-60 ppm for Burley and about 15-21 for flue-cured types. Deficient plants would show a lack of turgescence and a permanent withering of the younger leaves *(McMurtrey [1941])*. In case of Cu deficiency, copper sulphate application may improve the situation provided it does not exceed 5 kg/ha, since tobacco is sensitive to Cu excess *(Bacon [1950])*.

- *Manganese* deficiency is very rare. *Miner [1987]* reports that it occurs in flue-cured tobacco when sandy soils of the coastal plain of the S-E United States are limited to a pH greater than 6.2. Foliar Mn applied at a concentration of 0.45% three weeks after transplanting and again at five weeks increased leaf Mn concentration by 50-78 mg/kg. Band application of $MnSO_4$ in the base fertilizer was six times as efficient at increasing leaf Mn than broadcasting. But neither foliar nor soil applications of Mn significantly increased yield or concentrations of reducing sugars and total alkaloids in cured leaves compared to untreated controls.

Mn excess is more frequent, in acid soils, provoking symptoms not very different from those of deficiency: the young leaves are chlorotic, nearly white. The older leaves are covered with small necrotic spots. This Mn toxicity is associated with excessive soil acidity and can be corrected or prevented by liming. All ammonia fertilizers may increase soil acidity and aggravate Mn toxicity. Table 19 shows the influence of nitrogen levels at various pH on manganese nutrition, leaf appearance and Mn contents in leaves.

Table 19. Influence of N level on Mn contents in Burley leaves *(Whitty [1966])*

	Nitrogen level lbs/acre	Leaf aspect	Soil pH	Mn content in leaves ppm
Trial 1	60	normal	5.2	165
	240	normal	5.0	267
	240	chlorotic	5.8	387
Trial 2	120	normal	4.9	222
	360	normal	4.5	398
	360	chlorotic	4.5	585
	480	normal	4.5	555
	480	chlorotic	4.4	702

Even without any visible symptom of Mn toxicity on flue-cured tobacco excessive Mn and Fe concentrations in the leaves lead, after curing, to «grey» tobacco with a much reduced commercial value (Table 19).

According to some other authors, toxicity symptoms would appear only when the Mn concentrations exceed 3000 ppm *(Hiat [1963])*.

- *Molybdenum:* Mo deficiencies have been observed by *Steinberg [1953]* under glass, but have not been reported in the field.

4. Fertilization of tobacco in some producing countries

4.1 Flue-cured tobacco

– Principles

a) Nitrogen. It is essential, in order to obtain a good quality flue-cured tobacco (bright yellow colour, without any green, high sugar contents and low nitrogen contents) for the grower to control nitrogen nutrition. This is one of the reasons why this type of tobacco is grown on sandy soils poor in organic matter.

Although the nitrate-nitrogen amounts supplied by this type of soil are relatively low, it is important to fit the nitrogen dressing to the ability of the soil to release nitrogen through mineralisation or to lose nitrogen by leaching. For this reason, efforts have been made to devise means of predicting nitrification in the soil.

Finally, in certain cases, the ploughing in or the removal of grasses grown as catch crops or in rotation with tobacco permits some control of the N supply through the soil. The nitrate form is often prefered to the ammonium form, particularly when the soils have been treated with nematicide.

b) Phosphorus. Phosphate fertilizer dressings are always larger than the removals: placement is often recommended in order to promote early growth and maturity.

c) Potash. Potassium dressings (sulphate) should be moderate approximating to removals when the soil is high in K. Actually, especially when the soil is low in K, the amounts of K applied to tobacco often exceed 2 to 3 times those required for maximum yield, which would correspond to removals. This is justified on the basis that quality factors continue to improve with K additions beyond those required for maximum yield *(Sims [1985], Legett [1977], etc...)*

A small amount of muriate may be permitted if there is no other source of Cl (preceding crop, irrigation water, farmyard manure....) and if the soil is well drained.

d) Other elements. The fact that tobaccos are grown on very light and easily leached soils, often persuades the grower to apply magnesium and boron salts.

e) pH, liming. Acid soils (pH about 5.5) are preferred, better to protect Virginia tobacco against *Chalara elegans*. Dolomite is sometimes used for soil improvement but caution is needed as an increase in pH may accelerate nitrification.

— Practices

a) U.S.A.

American growers are generally advised to apply 40 to 80 kg of N and 72 to 144 kg K_2O per hectare for maximum yields of flue-cured tobacco: more fertilizer than needed for maximum yield. *Miner [1983]* reports that total rates of application in excess of 2250 kg/ha of 5-10-15 are used on flue-cured tobacco in North Carolina, this dressing being broadcast pre-transplant. This accounts approximately for 10% of the total operating cost (Table 20).

Table 20. Recommended amounts of K to apply to tobacco based on soil tests and other factors by selected laboratories in the USA and Canada *(Sims [1985])*

Location	Tobacco type	Soil test category† Very high	High	Medium	Low
		Recommended K application, kg ha^{-1}			
Kentucky ‡	Burley	0 (> 0.48)	0-225 (0.48-0.32)	225-335 (0.32-0.21)	335-450 (< 0.21)
Ontario §	Burley or flue-cured	100 (> 0.64)	110 (0.64-0.54)	110-130 (0.54-0.26)	130-270 (< 0.26)
Virginia #	Burley	100	—	—	350
	Flue-cured or dark	100	100	100-150	150-175

† Values in parentheses are soil test values (cmol [+] kg^{-1}) by the neutral 1 *M* NH_4OAc (Kentucky) and methods of *Ontario Ministry of Agriculture and Food [1983]*

‡ Anonymous [1984].

§ *Ontario Ministry of Agriculture and Food [1983].*

\# *Link [1982]* and *Jones [1982].*

b) France

The recommended fertilizer rates for Virginia tobacco are *(CFPPT [1986]):*

50- 70 kg/ha P_2O_5
180-200 kg/ha K_2O as potassium sulphate

for soils with normal phosphorus and potassium contents. These rates may be modified in the light of soil analysis.

Should the soil be cold or badly prepared, part of the P_2O_5 dressing may be banded at planting, to improve fertilizer efficiency.

Ca-Mg soil conditioners should only be used if prescribed by a soil test, and preferably applied for the preceding crop rather than immediately before tobacco plantation.

Nitrogen nutrition is one of the most important factors. Leaf analyses carried out in France have shown that good quality Virginia would result from moderate N supplies: 70 to 90 kg/ha according to yields. The mineralization of organic matter is sufficient, in most situations, to provide this amount. Therefore, N dressings should generally be low or even omitted. A slight excess of nitrogen will delay maturity, each kg of excess N over a 10 kg/ha dressing corresponding to one day of maturity delay. This excess would also increase the nicotine, and the organic nitrogen in the leaves which prejudices flavour. A large excess of nitrogen would be very harmful to the quality, leading to great difficulties during the curing process and especially to irregular yellowing. After two months of growth, the N supply must be very low, which means that any late N dressing would be prejudicial. That is why farmyard manure should not be applied before Virginia, and only little organic residues (straw...) should be left and ploughed in the soil.

In summary, N dressings normally range from 0 to 20 kg/ha N, with up to 40 kg/ha for very light soils low in organic matter.

c) Zimbabwe - Malawi

Fertilizer recommendations for Virginia tobacco in Zimbabwe are as follows (kg/ha):

	Sands	*Sandy loam*	*Sandy clay loam or heavier*
N	15- 70	10-55	20-55
P_2O_5	55-110	<———————>	160
K_2O	<———————	90-110	———————>
Borate	<———————	2-6	———————>

For very sandy soils: magnesium 45 kg/ha or dolomite 100 kg/ha. Boron is considered as essential on sandy soils (4.5 kg/ha of borax).

Nitrogen. The nitrogen rate should also depend on ploughing date:

	Sands	Sandy loam	Sandy clay loam or heavier soils
Early-ploughed or 2nd year	15-40	10-30	
Late ploughed	35-70	30-55	20-55

Ideally all the nitrogen should be applied as a pre-planting application of tobacco compound fertilizer. If more nitrogen is needed, some nitrate may be applied as a side-dressing within 3 weeks of planting.

Phosphorus. Phosphate is best applied in a water soluble form within a small volume of soil close to the seedling roots before or at planting. If insufficient P is supplied by the fertilizer mixture, single or concentrated superphosphate can be applied by placement. Higher P rates are advised on heavier soils in order to obtain good quality Virginia.

Potassium. On most soils an initial application of 90-110 kg/ha is recommended. Splitting this application or applying extra potash later in growth is not normally necessary. However, a response to extra potash applied 2 weeks before topping will give a response on sandy and acid soils. The common sources are sulphate and muriate, but on poorly drained soils and those with heavy texture, only sulphate should be used in order to produce a good quality tobacco.

d) India

Flue-cured tobacco is grown in 4 major agro-climatic zones:

Agroclimatic zone	*Soil type*	*Rainfall during growth cycle*
Traditional black soils (Andhra Pradesh)	Clay, clay loam, silty clay loams	13-47 mm + conserved moisture from N-E monsoon
Northern light soils (Andhra Pradesh)	Sandy loams, loamy sands	13-18 mm + irrigation
Southern light soils (Andhra Pradesh)	Red soils, red loams	501 mm
Transition belt (Karnataka)	Sandy loams, sandy clay loams, loamy sands	714 mm

Recommended rates (kg/ha):

	N	*P_2O_5*	*K_2O*
Traditional black soils	20	30-50	30-50
Northern light soils	30-40	60-80	60-80
Southern light soils	20-70	60-80	60-80
Transition belt	20-30	60-80	60-80

On all light soils, it is useful to apply N and K in two equal halves, one at planting and the other about 3 weeks later *(Gopalachari [1980])*.

4.2 Oriental tobaccos

– Principles

a) Nitrogen. Oriental tobaccos are grown on generally low fertility soils. Aroma, an essential characteristic of quality, is largely due to pedological and climatic conditions under which they are grown but also to the low level of N manuring. N fertilization experiments in Zimbabwe showed that the quality of oriental tobaccos is lowered by N fertilizer. Definitely for highest yield with the best possible quality it is advised, to apply only 10 to 15 kg N/ha on relatively fertile soils.

b) Phosphorus and potassium. Usually, PK fertilization combined with a very low N supply, improves the yield and the quality of oriental tobacco.

– Practices

In some oriental tobacco producing countries, manuring is traditionally done with farmyard manure or fold, and the greatest importance is assigned to the use of sheep and goat manure, which helps to develop the aromatic qualities of the leaves. Fertilizer is now more widely used than in the past, particularly with larger-leaved types.

In *Yugoslavia*, when there is a lack of manure, growers use small amounts of nitrate nitrogen (20-30 kg N/ha). In this case superphosphate (100 kg P_2O_5/ha) and potassium sulphate (60 kg to 100 kg K_2O/ha) dressings help to check the harmful effect of N on quality.

In *Greece*, relatively low rates (150-300 kg/ha) of Cl-free 4-8-8 or 4-8-12 are broadcast in the spring before planting.

Some trials were made in *Zimbabwe* to obtain tobaccos of oriental type. The recommended fertilization is:

5 to 10 kg N/ha	(as calcium ammonium nitrate)
40 to 80 kg P_2O_5/ha	(as superphosphate)
30 to 50 kg K_2O/ha	(as sulphate)

Potash fertilizer appears to be especially necessary in humid years. In addition, as in the case of Virginia, it is advised to apply MgO, boron and even a small amount of sodium chloride (20 kg/ha of Cl).

4.3 Cigar tobaccos — dark air-cured

— Principles

a) Nitrogen. From a general point of view, relatively generous nitrogen fertilization improves the yield and the quality of cigar tobaccos. The soil should be high in organic matter and large amounts of organic manure should be used.

b) Phosphorus. The advised phosphate dressings are generally smaller than for flue-cured tobaccos.

c) Potassium. It is absolutely necessary that cigar tobaccos have good combustibility. That is the reason why potassic fertilization is often very generous (150 to 250 kg K_2O/ha).

— Practices

In the Connecticut valley in the U.S.A., an area for cigar wrappers and binders, compound fertilizers are used, with the N-P-K ratio 2:1:2. ⅔ of the nitrogen is generally supplied in organic form (oil cakes in particular) and ⅓ as urea or nitrate. Phosphorus is given as dicalcium phosphate or superphosphate, and potash in the sulphate or nitrate forms. Rates are 225 Kg N, 120 kg P_2O_5 and 225 kg K_2O (as sulphate) per hectare. Sometimes farmyard manure is used at the rate of 25 t/ha, when the compound fertilizer amount is halved. Liming is advised only when the soil pH is lower than 5.

For cigar wrapper production in *Sumatra*, where soils are very rich in humus, the following inorganic dressing is applied: 15 to 20 kg nitrogen as ammonium sulphate, 45 kg P_2O_5 as superphosphate and 30 to 60 kg K_2O as potassium sulphate. Furthermore, the soils, except the silts, are often poor in P_2O_5 and 450 kg of basic slag is generally applied 2 months before planting.

In *Cuba* it is advised to apply 20 to 30 tons of farmyard manure per hectare, supplemented by a mineral fertilizer based on urea, ammonium sulphate, triple superphosphate and potassium sulphate.

In *Puerto Rico* growers may apply 400-500 kg/ha of compounds such as 9.12.15.

5. Economics: the influence of quality on selling price

Tobaccos will find buyers if the quality is good.

In a 3-year experiment carried out in S.W. of France, *Loué [1978]* showed the financial profit resulting from quality improvement in tobaccos grown under various K-fertilizer treatments applied to the preceding crops and to tobaccos (Table 21). The quality index including combustibility, the yield, the crop value and gross profit observed are given in Table 22.

Table 21

Treatment	1966-67 Wheat	1967 Ryegrass	1968 Tobacco
1	K0	K0	K0
2	K80 KCl	K80 KCl	K190 K_2SO_4
3	K160 KCl	K160 KCl	K300 K_2SO_4
4	K80 K_2SO_4	K80 K_2SO_4	K190 K_2SO_4
5	K160 K_2SO_4	K160 K_2SO_4	K300 K_2SO_4

Table 22

	Treatments 1	2	3	4	5
	Quality index (rated from 0 to 13)				
Lower leaves	1	2	3	4	5
Middle leaves	7	7	6	5	11
Upper leaves	7	5	7	8	10
	Yields kg/ha				
Whole crop	3534	3749	3793	3646	3717
	Crop value (FF/ha, 1977)				
Whole crop	15440	16301	16560	17070	18269
	Profit over K0				
Whole crop	—	861	1120	1630	2829

In China, *Liang Deyin [1983]* reported than when farmers started to use fertilizer on tobacco they soon found that nitrogen alone impaired quality and grade, resulting in lower prices. Summarizing the results of experiments at 17 locations carried out by the *Tobacco Research Institute* of Shantong Province, he has shown the beneficial effect of K_2SO_4 applications on the composition of tobacco, on the smoke value and on the net return of the crop: 997 yuan/ha without K_2O and 1325 yuan/ha with 75 kg/ha K_2O.

Leaf production has increased in nearly all producing countries. On the other hand there is a stagnation or reduction in cigarette consumption in many parts of the world, due to health warnings and ever increasing taxation of cigarettes. In some instances, unsold tobacco stocks amounted to significant tonnages, and lower grades were hardly sold even at lower prices. Tobacco growers must keep in mind that **QUALITY** means 1. possibility of marketing and 2. a more profitable price. As an example, the *European Community* prices established for 1985 showed the following differences between grades:

Grade	*Virginia*	*Burley F*
A	100 (4.62 Ecu/kg)	100 (4.51 Ecu/kg)
B	57	76
C	22	59

Leaf classification systems have been developed to enable the buyer to secure high quality leaf and to give the grower an incentive to produce high quality and so obtain a better price. Each lot of tobacco is identified prior to sale by colour and other characteristics such as plant position, maturity, leaf structure, body, width and length, burning, etc....

Those responsible for tobacco marketing at regional or government level should realise that quality will be more and more necessary for the export market.

6. Conclusions

There are few crops for which the market value of the produce is so much affected by fertilizer treatment. In the case of tobacco, the selling price of the crop depends to a large extent on the quality produced, and therefore is strongly influenced by an intelligent use of fertilizers: in this respect, nitrogen and potassium forms and rates are of prime importance.

In future, the world tobacco market will be governed more and more by quality factors, since supplies are abundant and there is little increase in consumption.

Only the best grades will command a profitable price, and low grades will enter the international market only with difficulty. Even in domestic markets, manufacturers will be more and more looking for good quality.

To reach this goal, growers will have to pay special attention to the NPK balance and avoid any excess of chlorine. This means that they will utilize tobacco fertilizer formulas based on potassium sulphate, the most usual Cl-free potassium fertilizer. And in many cases this recommendation will apply equally to the preceding crop to avoid any detrimental chlorine accumulation in the soil. They will also well adjust the form, the rate and the time of application of the nitrogen supply according to soil and tobacco type.

Tobacco is a high-value crop, with high production costs, lime and fertilizer amounting to only 8 or 9% of the total operating costs. Therefore it is profitable to use the most efficient fertilizers.

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