JJC/MS

WORKSHOP ON NITROGEN CYCLING IN THE WEST AFRICAN ECOSYSTEMS
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A DEFICIENCY OF THE SYMBIOTIC NITROGEN FIXATION IN A DRY TROPICAL AGROSYSTEM-THE NITROGEN CHLOROSIS OF GROUNDNUT (ARACHIS HYPOGAEA) IN SENEGAL

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SUMMARY

Various types of chlorosis on groundnut occur in Senegal. One that spreads over the Northern.mid Senegal is described here, and identified as a nitrogon chlorosis dus to a deficiency of N_2 fixation resulting from poor nodulation.

This chlorosis arises in acid soils, where there may be aluminium and manganese tosicity. No micronutrient deficiency has been found so far. Biotic factors among which the inadequacy of the rhizobium population and the attacks of nematodes may be responsible while the existing antogonism of actinomycetes toward Rhizobium would not interfere.

Liming and above all, organic matter application have prooved to be means of control of the chlorosis.

RESUME

Il y a différents types de chlorose de l'arachide au Sénégal. L'une d'elle répandue dans le Centre-Nord du Sénégal, est décrite ici puis identifiée comme une chlorose azotée par suite d'une déficience de la fixation symbiotique d'azote résultant d'une faible nodulation.

Cette chlorose s'observe en sols acides, avec toxicité aluminique et manganique. Aucune déficience en oligo-éléments n'a encore été trouvée. Les facteurs biologiques parmi lesquels l'état de la population de Rhizobium et les attaques de nématodes peuvent être en cause, tandis que l'antagonisme existant des actinomycetss vis-à-vis du Rhizobium n'aurait pas d'effet.

Le chauiaga et surtout, l'apport de matière organique constituent des moyens de lutte contre cette chlorose.

I - INTRODUCTION

In Senegal, different types of chlorosis of groundnut have been observed. They generally show up in well defined areas often known as "yellow patches" (1).

A first type of chlorosis is related to a high soil pH. It occurs :

- at sites of burning where houses were located years ago (2) or where the crops residucs (straw) have been burnt before the rainy season.
- at the place of termite maunds recently leveled
- in soils where irrigation with water containing large amounts of basic cations increased pH well above 8,0.

A second type of chlorosis may occur in areas where water-logging prevented diffusion of oxygen in the soil, thus inhibiting nodulation and nitrogen fixation. This type of chlorosis has been observed in Casamance in shallow depressions which favor waterlogging.

A third type of chlorosis which will be described here, occurs in acid soils. It was observed in tho regions of Louga, Thies and Diourbel and in the northern part of Sine Saloum, which are caracterised by an irregular rainfall of 300 to 700 mm during 3 months from July to october and usually a groundnut millet rotation sometimes accompanied by a one or two years fallow.

II - SYMPTOMS OF THE CHLOROSIS OCCURING IN ACID SOILS

Symptoms of this chlorosis are described here from observa-tion made during the 1378 rainy season at Thilmakha (region of Thies) where the average rainfall is 500 mm, The soil is a dior soil.

Tab. I : physico-chemisal caracteristics of the Dior soil

Organic matter	clay + limon	Sand	C.	N	C/N	Exchangeable bases	pH water 1/2,5
0,3 %	3,3 %	96,4 %	2 %	0,18 %	11 g	0,70 mé	5,5

Yellow patches made up of chlorotic groundnuts were compa-red with non chlorotic adjacent areas which were used as controis.

Faint yellowing of leaves in first seen between the 20th nnd the 30th day after sowing. The plant growth and emergence of new leaves is slowed down. The severity of this type of chlorosis is variable :

(1) - The plant may turn yellow and remain dwarf, It wilts and consequently dies after the 60th day.

(2) - The plant may be iess affected by the chlorosis. It turns yellow but keeps growing slowly (fig.2).

(3) - Faint yellowish plants may recover after the 30th day (fig 1) (such a recovery was also observed in green-houses cxperiments after the 55th day), New green leaves emerge and normal growth rate is rapidly restored.

The total number of flowers produced by the chlorotic plants is lower than by the non chlorotic ones and the rate is slower (fig.3). The number of nuts in the chlorotic plants is 40 % less than in the non-chlorotic ones.

The root system of chlorotic plants is more or less atrophied. Two kinds of atrophied root systems were observed.

(1) - Root systems made up of the top root with only one or two lateral roots, no radicles (fig.4). Type 1

(2) - Root systems with many lateral roots but only a few radicles. Type II

There were very few nodules on the roots of chlorotic plants. While the number of nodules grew steadily till tho 70th day on the non chlorotic plants, it stayed at a low level after the 30th day on the chlorotic plants (fig.6) : on the 70th day, ths average number of nodules (mean of 20 plants) is 130 on' the non chlorotic plants and 10 only on the chlorotic ones.

Moreover a great number of brown protrusions were found on chlorotic plant's roots (fig.5). The exact nature of these U,5 mm long cone-shaped protrusions, which are filled up with bactoria, is still obscure.

III - INDUCTION OF THE CHLOROSIS BY A NITROGEN DEFICIENCY

By applying 100 kg N/ha as ammonium nitrate to field grown groundnuts, BLONDEL (1968) obtained a satisfactory recovery of chlorotic plants.

Under green house conditions, the chlorosis was reproduced on a soil from Thilmakha. Urea application (equivalent to 100 kg N/ha nitrogen) eliminated the chlorosis symptoms.

Therefore, the chlorosis studied here appears to result from a nitrogen deficiency.

This conclusion was confirmed by nodules counts (fig.6) and by acetylene reducing activity expressed per plant, which was significantly lower *in* chlorotic plants than in non chlorotic plants (fig.7).

Moreover, the specific acetylene rsducing activity of nodules from chlorotic plants was generally lower than that of nodules from non chlorotic ones (table II). It may be attributed either ta infection by less efficient strains or to a decrease of the photosynthetic activity which caused a reduction in the energy supply of the nodules of chlorotic plants.

Table II : Specific acetylene reducing activity (micromoles acetylene /mg nodules dry weight/hour) -. Thilmakha '78 - average of 20 plants.

Number of days after sowing	35	47	55	62	70	81
Chlorotic plants	192	626	267	232	119	166
Non chlorotic plants	721	121*	509	317	406	306

* This low level of activity is due to a 15 days drought which affected much more the well developped non chlorotic plants than the chlorotic ones.

IV.- CAUSE OF THE DECREASE OF NITROGEN FIXATION IN CHLOROTIC PLANTS

Groundnut is more affected by chlorosis when the rainfall is inadequate or when thc seeding is delayed. However, chlorosis being reproducod on soil samples under green house conditions, the soil itselfseems to be mainly responsible for this deficiency, The different soil characteristics that have been thought to cause the decrease of nitrogen fixation by groundnut are as follows :

1/ - The mineral stetus of the soil

The soils in which the chlorosis is mostly observed are of the Dior type tropical ferruginous and deep soils. They arc mainly sand (96 %) with only 3 to 4 % of clay and 0,3 % of organic matter.

They progressively become acid under cultivation with specific intensive agricultural practices (9.10.11.)

a - Soil acidity

BLONDEL (3) first noticed that in the case of yellow dwarf plants of groundnut, the pH (water pH 1/2,5) was below 5,0 (3).

Later PIERI (8) showed "chat therc was only a loose relation between water pH and the chlorosis of groundnut, around the value of 5,0 (measured by the water pH 1/2,5 method) and that this pH varies much in the soil profile,

Measures of pH made on rhizosphero soils (Thilmakha 1978) showed that in most cases the PH of the chlorotic plant rhizosphere stays between 4,7 and 5,2, but some values as high as 5,7 were also found, Besides, the pH of the non chlorotic plant rhizosphere sometimes was as low as 5,4 to 5,0.

b - Aluminium, toxicity

According to PIERI (8) a better approach of the noxiaus effects of soils acidity would be to measure the saturation of absorbing complex with exchangeable aluminium. In an experimental study in glasshouse, he showed , that aluminium is toxic to the nodulation when the rate of saturation of the absorbing complex is more than [illegible] when it is more than 50 % in the case

Exchangeable aluminium appears in the Dior soils when the measure of water pH is well below 5,5. But the pH KCl which measures the exchange acidity is then more sui-table.

c - Manqanese toxicity

Mineral analysis of the aerial vegetation reveals a higher proportion of manganese in the chlorotic plants. (777 ppm) in comparison to non chlorotic plants (267 ppm), at the 21st day after sowing (Thilmakha 1978 - PANTIER).

The manganese would be toxic to the groundnut whcn the proportion in the leaves is more than 600 ppm (15).

d - The microelement nutrition

The chlorosis is observed in condition of mineral fertilization : 150 kg/ha of 8.18.27 (containing also sulfur) on groundnut and 150 kg/ha of 14.7.7. on millet in rotation,

But some micronutrients are necessary for the nodulation of groundnut, among them molybdenum, Boron, Cobalt , Iron, Copper and Zinc,

A significative effect of Molybdenum was obtained in field trials (16). But it was not in condition of chlorosis.

On the apposite, a foliar spreading of a complete micronutrient solution for legumes, has no effect on the chlorosis (Thilmakha 19'78).

2/ - The influence of biotic factors

a - Inadequacy of the rhizobium population

At Thilmakha, rhizobium population was shown to be ten times lower in soils with chlorotic plants than in soils with non chlorotic plants. On the other hand WEY (personal comunication) eliminatcd chlorosis by inoculating groundnuts with CB 756 strain.

But this results could not be confirmed in the field. Since nodulation of bydroponically grown ground-nuts inoculated by a suspension of soil with chlorosis plants did not differ from nodulation of plants inoculated by a supension of control soil, Rhizobium populations alone were not thought to be responsiblo for the poor nodulation that occured in the field in chlorotic plots.

b - Microorqanisms antasonistic to rhizobium

PANTIER (12) found actinomycetes antagonistic to rhizobium in soils of Senegal.

But the numbers of these antagonistic actinomycetes . . [illegible] in soils where chlorosis is observed did not differ from that existing in soils where no chlorosis occured (PANTIER -Table III).

Table III - Number of actinomycetes antagnnistic to Rhizobium in one gram of soil - Thilmakha (1978 average of 5 soil samples)

	Actinomycetes	Antagonistic actinomycetes
Soil with chlorotic plants	1,7 10^5	9,5 10^3
Soil with non chlorotic plants	2,8 10^5	9,4 10^3

Therefore the interference of actinomycetes probably cannot be held responsible for the lower nitrogen fixation of chlorotic plants.

c - Influence of. nematodes

In Upper Volta chlorosis was clearly shown to be caused by nematode attacks (17).

1 n Senegal , according to the nematodes counts by GERMANI, the contamination of roots by Scutellonema cavenessi is much greater in chlorotic plants than in non chlorotic ones.

Table IV - Numbor of nematodes Scutellonema cavenessi in tho roots of chlorotic and non chlorotic plants - Thilmakha (1978 - average of 10 plants)

Area with :	Numbor of nematodcs	
	Soil	Root
Non chlorotic plants	200	2 580
chlorotic plants	880	20 951
Chlorotic plants years beforc t no treatment with nemagon	506	16 420
Chlorotic plants years before t treatment with nemagon	0	0

Up to now, it has not yet been possible to reproduce tho chlorosis by inoculation of a non chlorotic (normal) soil with nematodes in laboratory conditions,

In a field trial, tho fumigation with nemagon restored the vegetative growth of groundnuts. Nevertheless, chlorosis was not eliminated on the chlorotic areas treated with nemagon. The plants had a perfectly well dcveloppod root system without protrusions but very few nodules.

Table V : Effect of soil fumigation with a nematicide (Thilmakha 1978 - average often plants)

Area with	Dry weight plants gr	Number of nodules	Type of root (fig.4)	pH
No chlorotic plants	8,04	28,1	III	5,4
No chlorotic plants + nemagon	18,12	39,8	III	5,4
Chlorotic plants	3,27	2,5	I- II	5,0
Chlorotic plants + nemagon	11,81	1,0	III	5,1

V - CONTROL OF CHLOROSIS

Two methods for controling chlorosis have been empirically found to be efficient : liming and organic matter application.

In a field trial at Thilmakha, liming was applied at the rate of 600 kg/ha, by pelletizing each grain of groundnut. The area coverod by the chlorosis has been reducod in the plots treated with lime , but still some yellow plants could be seen and the vcgetation had not totally recovered.

Farm-yard manure has also been applied since 1973 in the same trial. Every two years, the plots havc received 10 tons dry matter per hectare before groundnut planting. After the second application of manure, yellow patches had been reduced considerably, and after the third application, 5 years later, not a single symptom of chlorosis could be seen.

Nevertheless this rate of manure application is very high, compared to the quantity of organic matter the senegalese farmers can rely on (18).

VI - CONCLUSION

This symptom of chlorosis which occurs in acid soils appears to be related to the following characteristics

(1) - Mineral toxicities
(2) - Low rhizobium populations
(3) - High nematode populations.

It is not yet known wether the decrease in nodulation and N_2 fixing activity of the legume results (1) from a poor growth of the plant (due to mineral deficiencies or nematode attacks) -(2) from low Rhizobium populations or from some mechanism prevonting infection and nodulation.

Further investigations are neoded in order to elucidate the interactions between the plant, soil mineral factors and soil microorganisms. The results of such investigations should hslp to develop cultural practices which could promote N2 fixation by preventing the effect of limiting factors in Sahelo-soudanian agro-systems.

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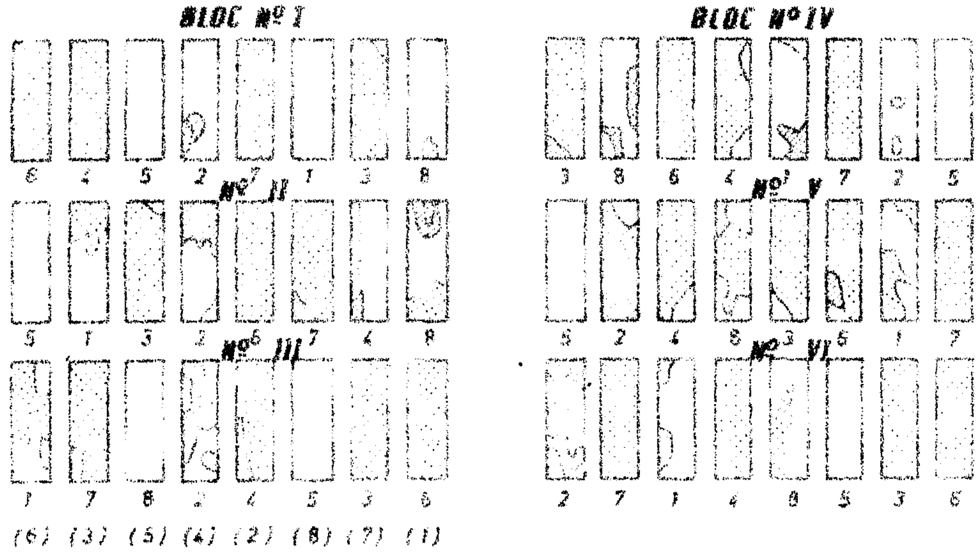
FIG. 1 : ESSAI INFLUENCE DES TECHNIQUES CULTURALES SUR LA NODULATION THILMAKHA

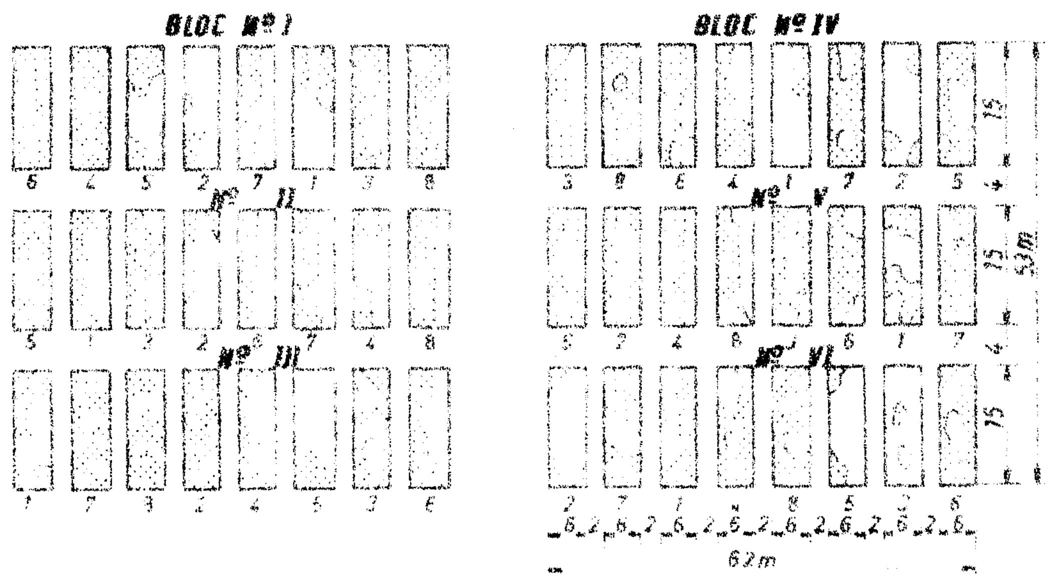
Sites of chlorosis August 1978

SURFACES CHLOROTIQUES AOUT 1978



Sites of chlorosis August 1974

SURFACES CHLOROTIQUES AOUT 1974



Zone de reverdissement – Recovery area

Zone saine – Normal area

FIG. 2 : POIDS SEC DES PLANTES

DRY WEIGHT OF THE PLANTS

(THILMAKHA 1978)

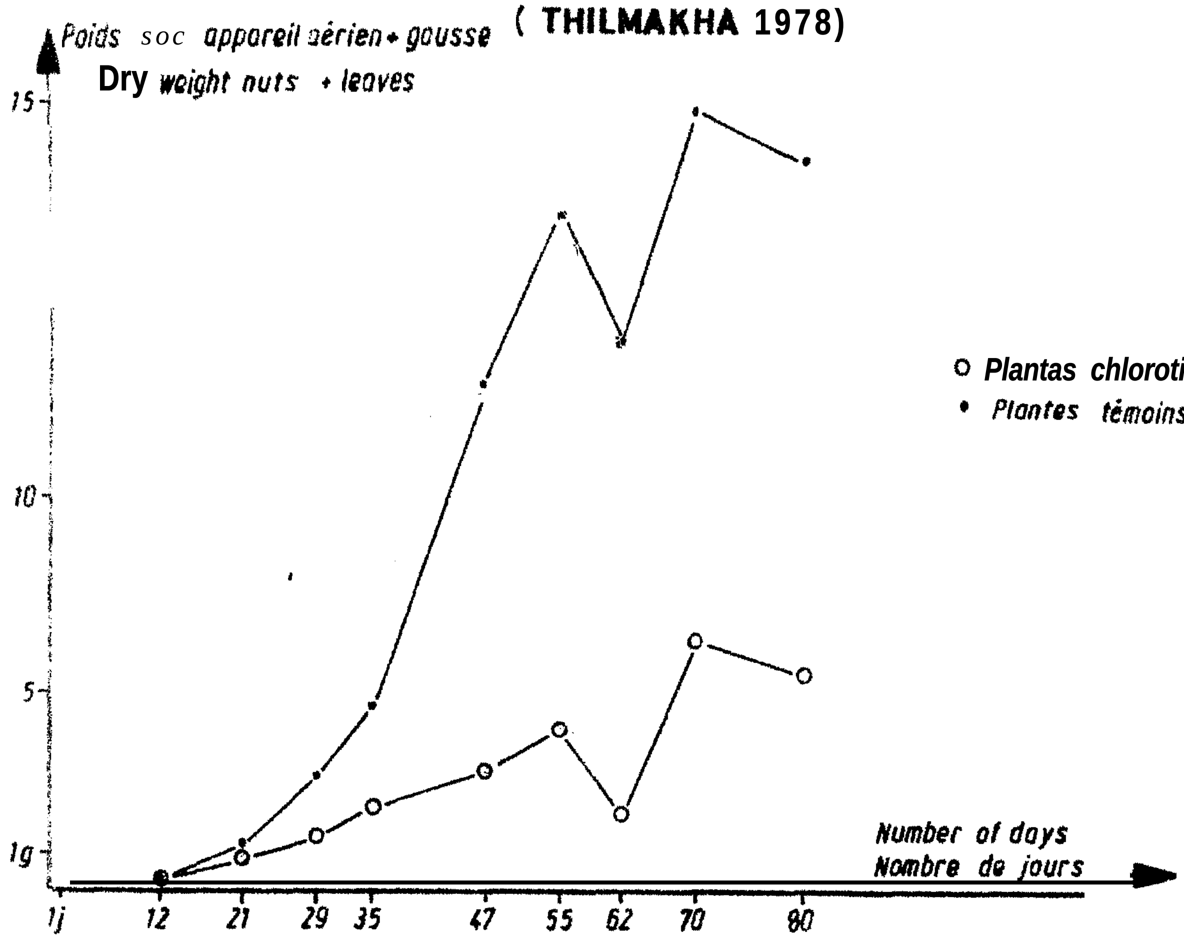
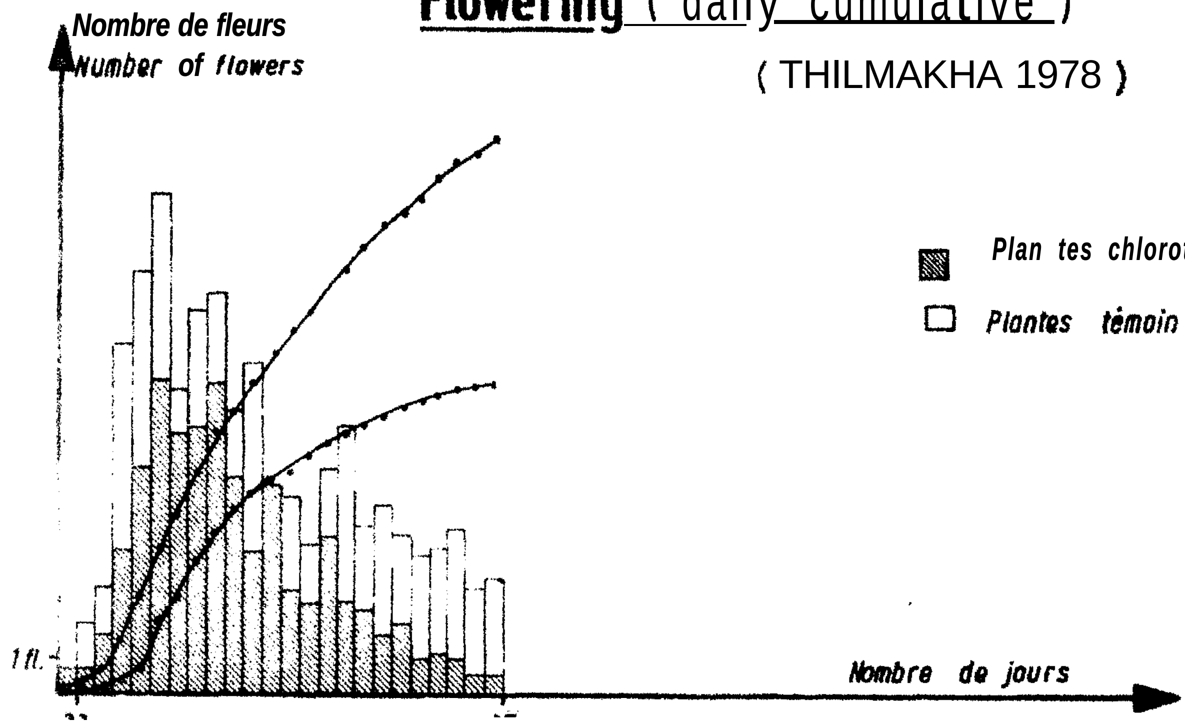


FIG. 3 : FLORAISON (journalière- cumulée)

Flowering (daily cumulative)

(THILMAKHA 1978)



(FIG. 4) RACINES D'ARACHIDE (56e JOUR)

ARACHIS ROOTS

TYPE III

Plante non chlorotique - Non chlorotic plant

TYPE I

TYPE II

Plantes chlorotiques - Chlorotic plants

(FIG. 5) RACINES LATERALES "PROTUBERANCES"

SIDE ROOTS "PROTRUSIONS"

Nu[illegible]er of nodules **THILMAKHA 1978**

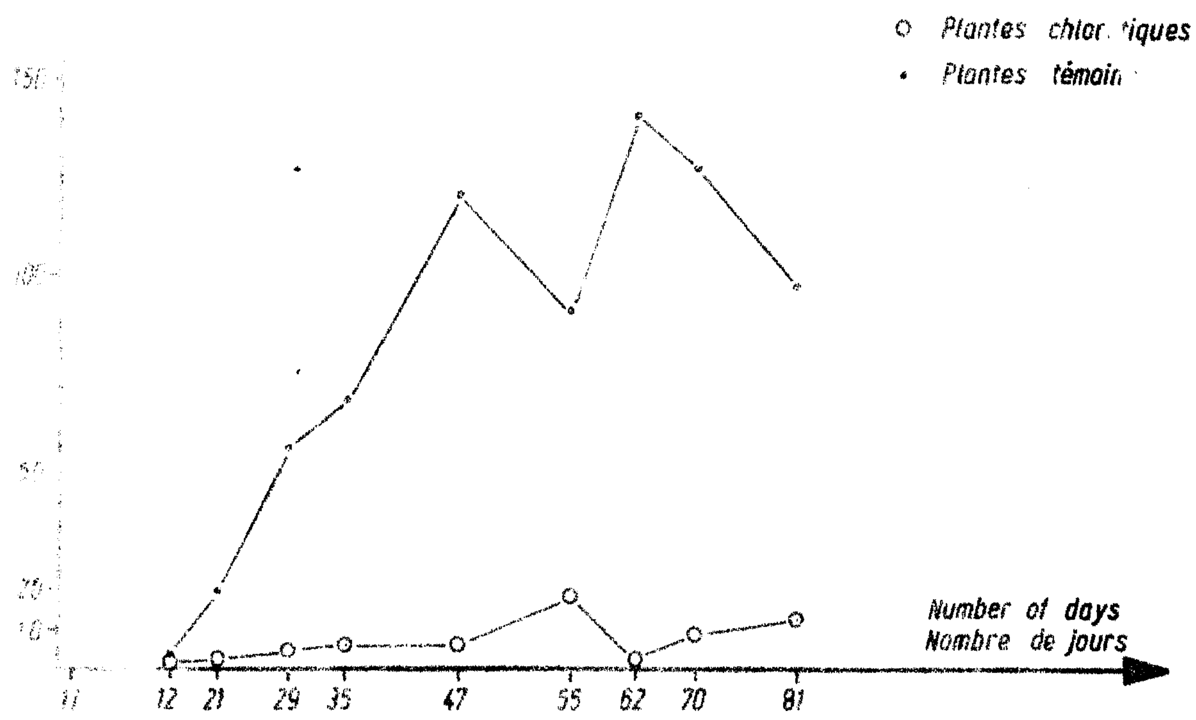


FIG. 7 : ACTIVITE REDUCTRICE ACETYLENE PAR PLANTE

Reduction of Acetylene per plant

Nanomoles of acetylene per hour per plant
Nanomole d'acétylène par heure par plante **(THILMAKHA 1978)**