CONTROL OF PHYTOPARASITIC NEMATODES IN THE BASSIN ARACHIDIER OF SENEGAL

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Gaetano GERMANI*, Pierre BAUJARD* & Michel LUC**

Nématologistes ORSTOM* Centre ORSTOM de Dakar, BP 1386 Dakar, Sénégal
* * Muséum national d'Histoire naturelle,
Laboratoire des Vers, 61 rue de Buffon, 75005 Paris, France

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Cover : Effect of nematicide treatment on groundnut in the Kebemer area, Senegal.

INTRODUCTION

Groundnut culture occupies a dominant economic position in Senegal : nearly one million ha. of groundnuts are cultivated annually and grain sales represent 50 % of farm revenues in a country where farmers constitute 70 % of the population. Groundnut oil and oil cake represent more than half of Senegal's export earnings and straw provided by the aerial parts of the plant support husbandry which is locally important although difficult to economically quantify.

Originating in South America, and introduced by the Portugese in the sixteenth century, groundnut were increasingly accepted by Senegalese farmers and are now considered part of their traditional agriculture. It is presently the only cash crop and occupies an important position as a leguminous rotation crop in the production of the staple foods millet and sorghum.

The bassin arachidier consists of more than 600,000 ha (fig. 1) in the Sudano-Sahelian zone of Senegal. The zone is characterized by a long dry season (October to June) and a short rainy season (July to September) during which rainfall is highly variable and in recent years never surpasses 500 mm.

Soils of the region are generally sandy and deficient in most plant mineral nutrients. The two major soil types are described as «dior» in which clay fractions range from 6-12 % and «deck» which contains 15-20 % clay and are notably phosphorus deficient.

While insufficient and irregular rainfall is the major limiting factor to crop production in the bassin arachidier, plant pests and parasites also cause considerable crop losses. Plant parasitic nematodes, in particular ***Scutellonema cavenessi,*** are among the most important of these crop loss agents.

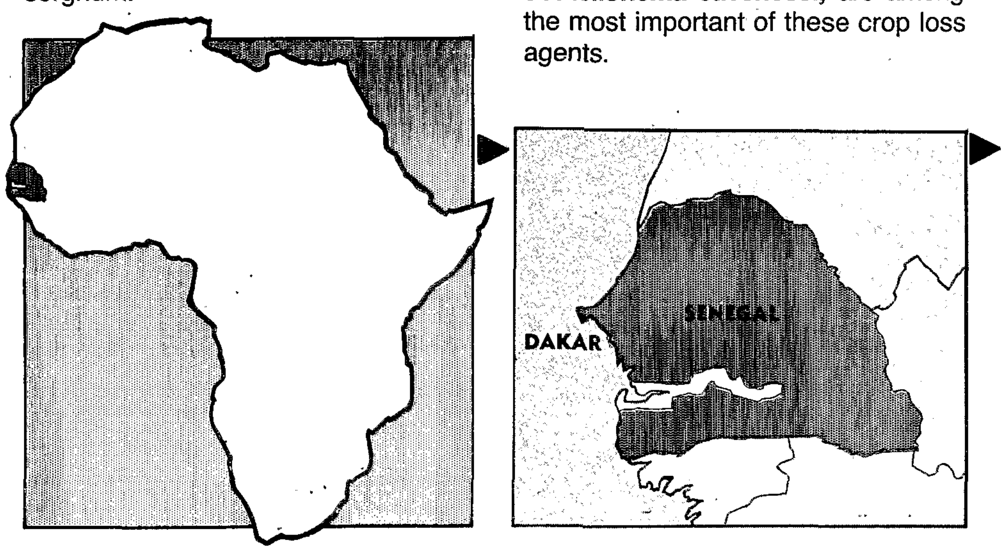


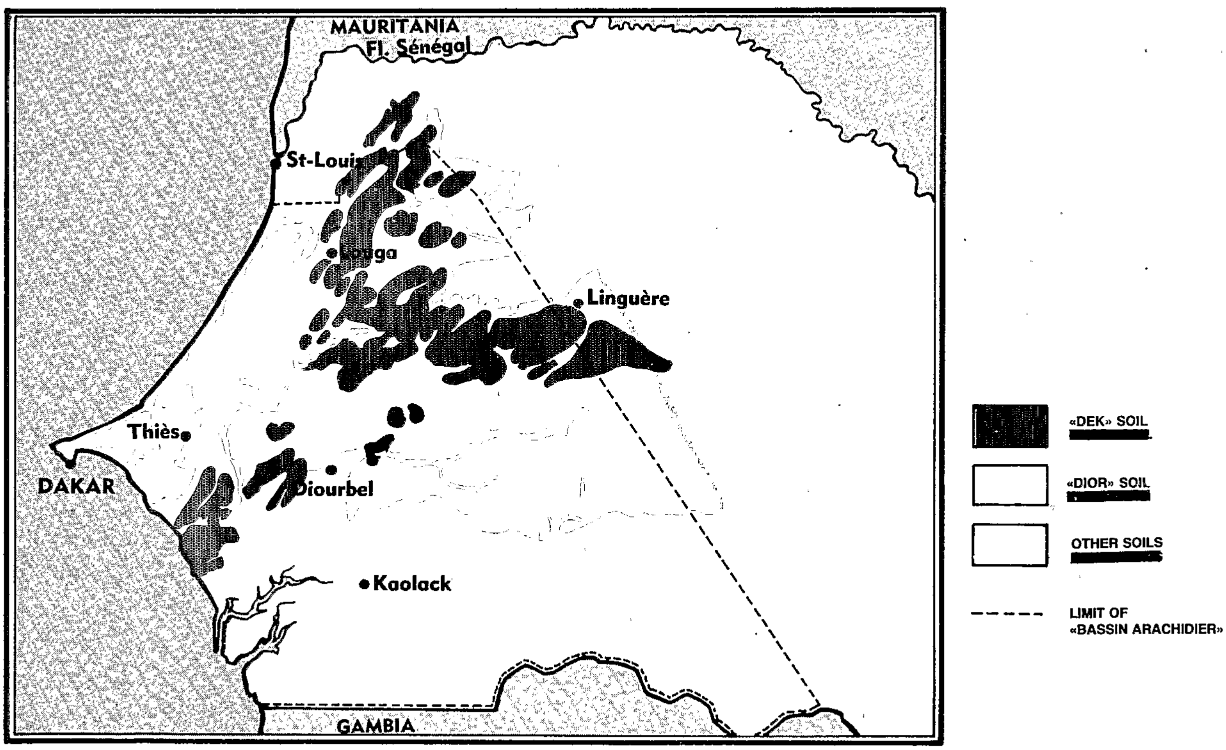
FIG 1
Distribution of Dior and Deck soil types in Senegal's bassin arachidier

THE NEMATODE *SCUTELLONEMA CAVENESSI* SHER 1964

This nematode or roundworm is approximately 1 mm long and .03 mm wide. It inhabits the soil and penetrates and parasitises the roots of a large variety of plants. It was originally discovered in Nigeria and has since been found from South Africa to the Congo. In the "bassin arachidier" of Senegal high soil infestation levels of ***S. cavenessi*** are ubiquitous. The nematode is particularly suited to this zone because its life cycle (fig. 2) is well adapted to the elevated soil temperatures and the alternating cycles of short rainy seasons followed by long drought periods.

During the dry season, the adults and the fourth stage juveniles exist in an anydrobiotic state (fig. 3) of near dessication in which their bodies are tightly coiled, and demonstrated no detectable sign of metabolism.

They are capable of surviving in dessicated soils in this state for several years even at the high temperatures (50° at -5 cm) attained in soils unprotected by plant canopies. The nematodes revive at the first seasonal rains, copulate, and begin egg production in 5 to 9-days. Infective, second stage (L 2) larvae (fig. 4)



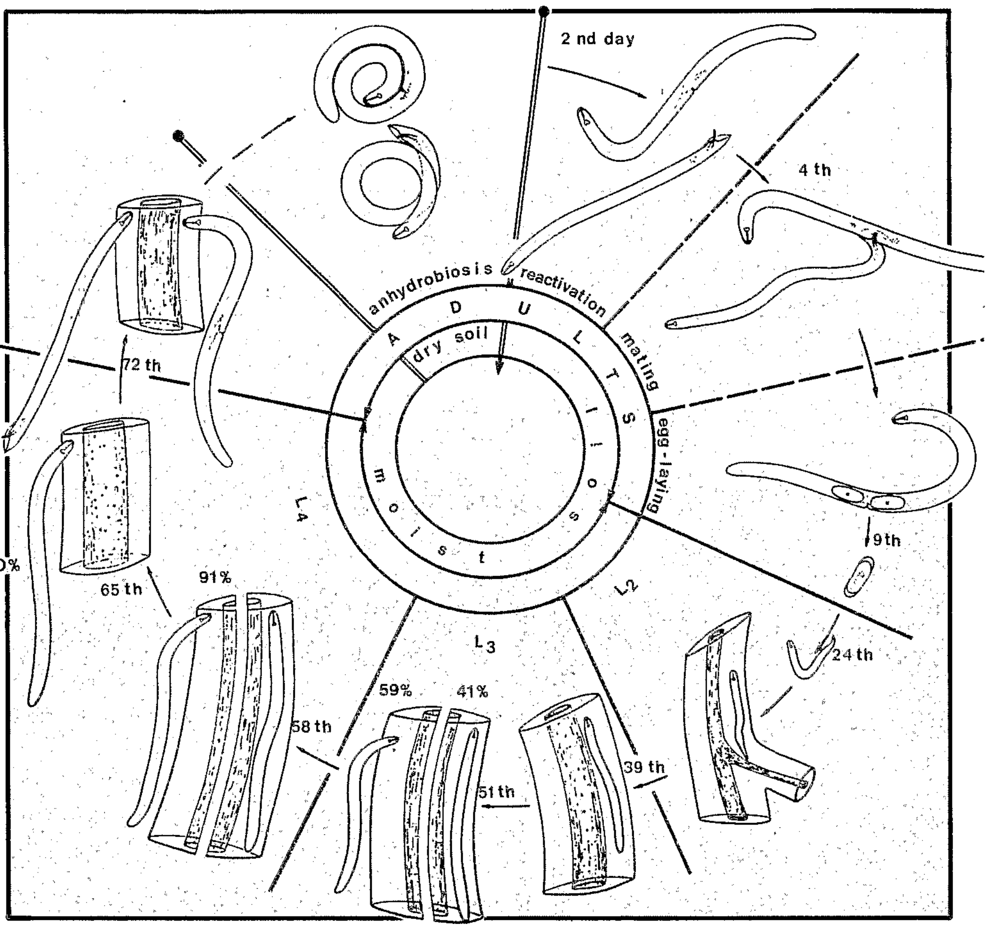


FIG 2
Life cycle
of *Scutellonema cavenessi*

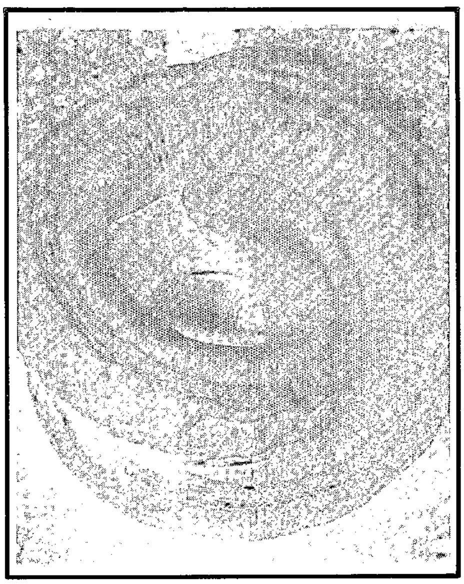


FIG 3 Tightly coiled anhydrobiotic nematode

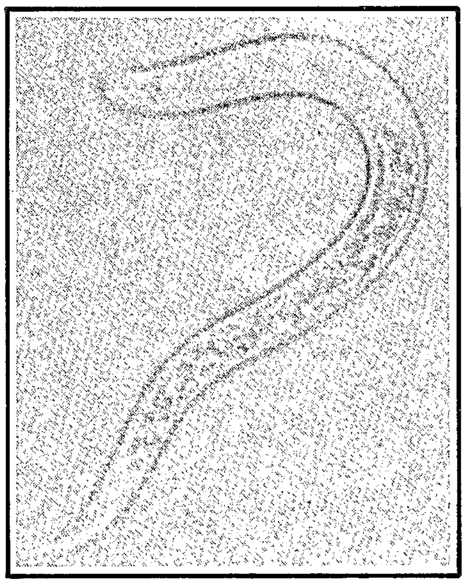


FIG 4 Infective juvenile (2nd stage) of *Scutellonema cavenessi*

hatch from the eggs and, attracted by groundnut roots, penetrate the cortex and feed on cell contents. During this phase of its life cycle the nematode is completely endoparasitic. Two larval molts occur in the endoparasitic phase and fourth stage larvae exit the roots where, along with adults of both sexes, they feed semi-endoparasitically by penetrating cortical tissues with the anterior portions of their bodies (figs. 6-7).

Thus, prior to the end of the groundnut vegetative cycle, adults and fourth stage larvae have reentered the soil environment where they become anhydrobiotic when the soil moisture levels decline.

This period of anhydrobiosis is a diapause rather than simple quiescence since nematodes can be reactivated by moistening the soil but will not reproduce or infest plant roots until a number of months have been passed in the anhydrobiotic condition.

FIG 5 ***S. cavenessi* second stage juvenile in groundnut root tissue**

Development from egg to adult requires 65-72 days and ground cycles range from 90-120 days so that only one generation of ***S. cavenessi*** is produced annually. This, in conjunction with the required diapause during the annual drought conditions, demonstrates the degree to which the biology of the nematode corresponds to the environmental demands in the bassin arachidier. All of the nematode's activities occur in the groundnut rhizosphere to a depth of 25-30 cms.

DAMAGES CAUSED

As with most phytoparasitic nematodes, the host-parasite interactions which result in host damage are not well defined. In addition to plant substances diverted to the be-

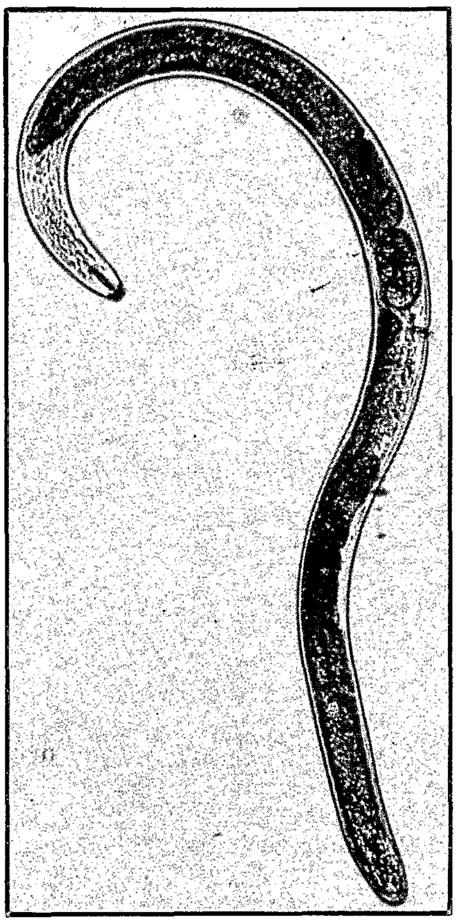


FIG 6 ***S. cavenessi* female extracted from soil sample**

nefit of the parasites, nematode-secreted toxins may be involved. In groundnuts, infection by ***S. cavenessi*** seriously reduces the extend and activity of rhizobial nodulation (fig. 8). The cowpea strain of ***Rhizobium*** infects groundnut roots and fixes atmospheric nitrogen which is then utilized by the plants. ***S. cavenessi*** infested plants are thus deprived of much of the benefit of the ***Rhizobium*** symbiosis, and are smaller, more chlorotic and produce fewer pods than non-infested plants. Certain acid soils which favor the development of ***S. cavenessi*** contain high levels of free aluminium. A combination of reduced nodulation and aluminium toxicity result in symptoms called "yellow patches" (taches jaunes) in which the chlorotic foliage presents a startling yellow appearance. ***S. cavenessi*** has also been observed to reduce mycorrhizal root-fungus symbiosis which in turn reduces the amount of phosphcrus available to the plant, and forsters drought sensitivity.

No difference in host suitability or sensitivity have been noted amoung groundnut cultivars used in Senegal.

The action of ***S. cavenessi*** in reducing millet and sorghum yields appears to be more direct since bacterial symbioses are not a factor. Wounds, toxins and reduced mycorrhizal infection may all interact to cause cereal losses.

FIG 7 ***S. cavenessi*** **female with anterior body portion embeded in groundnut root**

TREATMENT

PRODUCTS USED

Modern, granular systemic nematicides cannot be used in the Sudano-Sahelian zone because soil moisture conditions are generally unfavorable to their activity. The only suitable nematicides are liquid fumigants which act by releasing toxic gases, when injected into the soil.

Most investigations on control of ***S. cavenessi*** have been conducted with dibromochloropropane (DBCP). DBCP or Nemagon ® is applied at the first significant* rainfall of the season which also corresponds to the sowing date. It is applied at sowing because the soils are unsuitable for fumigation during the dry season and because the nematode has been found to be most sensitive to nematicide toxicity during the period when it is reviving from the anhydrobiotic state. Because it is hightly sensitive just following the first rainfall and because it generally inhabits only the soil plow-layer, it has been possible to :

1) diminish the dose/ha from 45 l to 15 l (in 85 l of water);

• Rainfall at least equal to 20 mm.

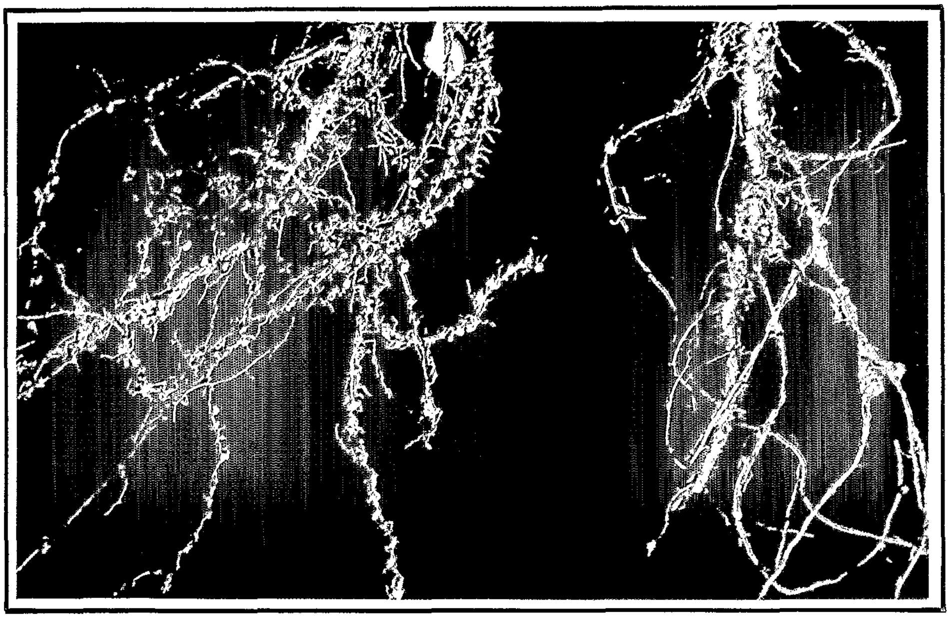


FIG 8
Groundnut roots infested (right) and non-infested (left) by plant parasitic nematodes. Note the greater tissue development and Rhizobial nodulation in non-infested plants.

2) reduce treatment depth from 25 to 15 cm, which reduces the effort needed to pull the application machinery. In spite of these modifications, nematode control is excellent. In some experimental plots, ***S. cavenessi*** remains undetected 8 years following treatment. Further, the effort of fumigation is minimized by combining the operation with that of sowing. DBCP evaporates rapidly from the soil without effecting groundnut germination which begins within several days after sowing.

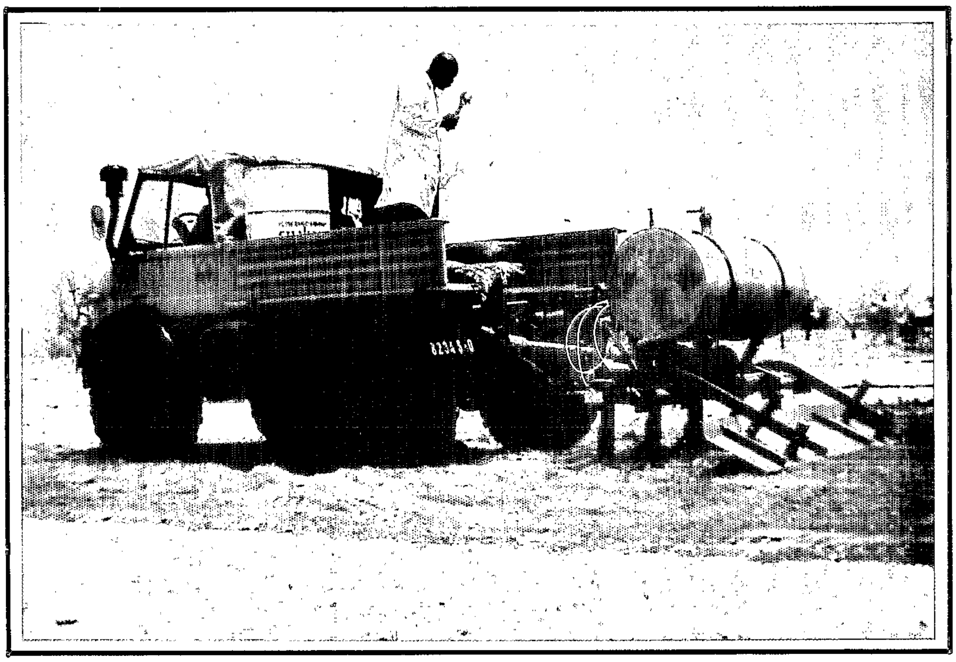
It has been observed that nematicide treatments are most efficacious in dior soils than in the heavier deck soils.

It should be noted that use of DBCP is forbidden in the USA and a number of other countries, primarily because of groundwater contamination. However, conditions of DBCP employment in the bassin arachidier are considerably different than in regions which have experienced problems. For example, in California, DBCP is applied in successive years at rates of 45 l/ha and thus it is not surprising that the shallow (– 3, – 6 m) groundwater tables become polluted. In Senegal, treatments of only 15 l/ha would be applied no more frequently than 5 year intervals and in regions with groundwater tables - 30, -300 m below the soil surface.

The risk of groundwater contamination under such conditions appears minimal. High soil temperatures and sandy soils in the bassin arachidier also hasten the volatilization of DBCP reducing the risks of environmental pollution. It is hoped that future research will further reduce the possibility of pollution by identifying biodegradable, efficacious fumigant nematicides for this region.

FIG 9

Large surface fumigation rig. This «Stericulteur Seisson» possesses 7 injections shanks and is shown attached to a Unimog ® all terrain vehicle.



TRACTOR DRAWN-MACHINE

The "Stericulteur Seisson" operates with 5 injection shanks which deliver the nematicide/solvent mixture at the desired depth. The application rate is regulated by forced pressure in a 500 liter reservoir. This rig, drawn by either a 45 CV tractor or an all terrain vehicle such as a Unimog , will permit treatment of 2 ha/h excluding service time.

HORSE-DRAWN MACHINE

This machine was developed jointly by specialists of ORSTOM, ISRA, CEEMAT and a private firm, SISMAR. It permits simultaneous sowing and soil fumigation (fig. 10). A chisel injector fed by a 30 liter reservoir is attached to a reinforced frame of a "Supereco" ® planter. Nematicide flow is drawn by a pump at a rate regulated by the advancement of the rig. Nematicide is applied at a depth of 15 cm in a line 4 cm from the line of sowing. One half of a hectare can be treated daily with a horse drawn fumigation rig, or approximately one quarter of the normal surface planted by a Senegalese farmer.

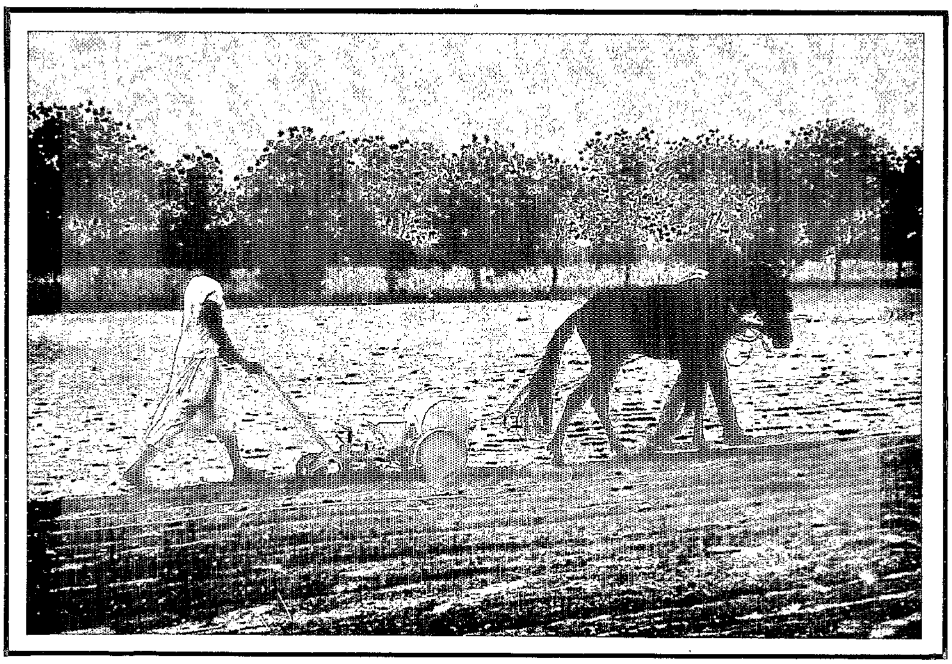


FIG 10
Horse drawn fumigation rig which sows groundnuts in the same operation.

RESULTS

DIRECT TREATMENT EFFECTS

When nematicide treatment are well applied, levels of phytoparasitic nematodes often attain non-detectable levels. The effect on groundnuts reflect this excellent level of nematode control. Plants are more vigorous, taller and leaves are greener (figs. 11, 12, 13). In the experimental plots, these superior plants yield 129-141 % higher groundnut weight than nematode infested plants and straw is increased by 107-279 % (figs. 14, 15). In farmer field trials 20-220 % groundnut gains and 40-270 % straw gains have been recorded. The greater variability in on-farm trials is likely due to variation in soil type, nematode infestation level and annual rainfall levels.

An important aspect of soil fumigation is the reestablishment of optimum rhizobial and mycorrhizal relations with the groundnut plant which insure adequate supplies of nitrogen and phosphorus (fig. 15).

PERSISTANCE OF TREATMENT EFFECTS

As previously described, populations of plant parasitic nematodes reestablish very slowly following soil fumigation which is relected in crop performance. Average groundnut yield increases of 23 and 27 % and straw increases of 40 and 51 % (figs. 15, 17) have been measured in the second and third years, respectively, following treatment. Millet and sorghum yields were augmented 17-221 % and 40-440 %, respectively, in the year following treatment (figs. 16, 17). These strong residual effects are

FIG 11
Experimental plots showing effect of nematicide treatment on groundnut growth.

FIG 12
Effect of large scale nematicide treatment is shown in plants on left.

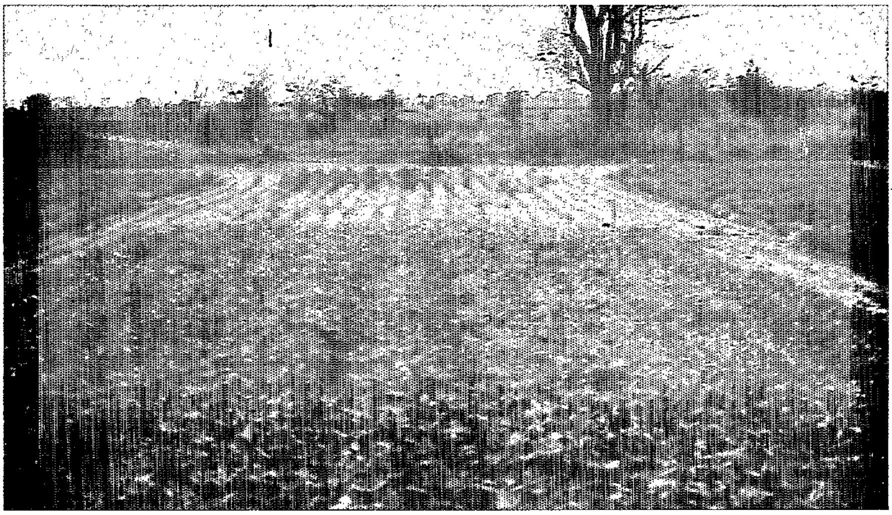


FIG 13

Effect of nematicide treatments on the disease called «yellow patches».

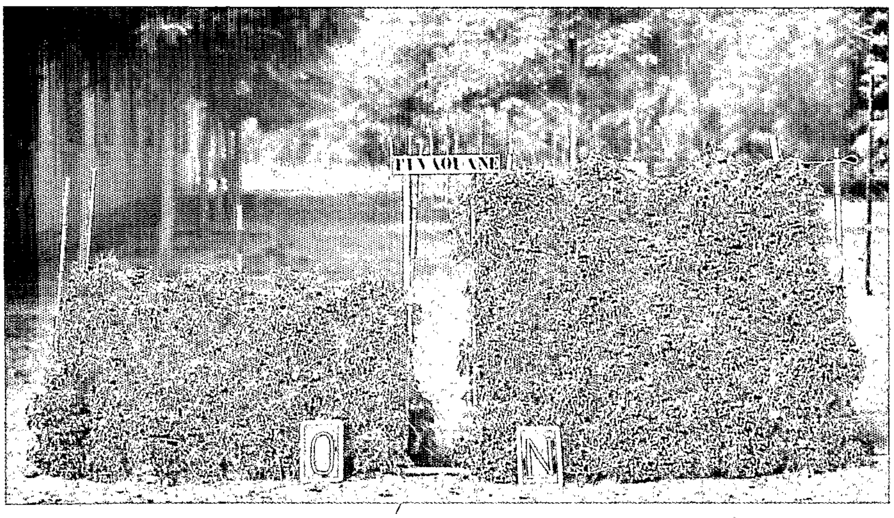


FIG 14
Groundnut harvested from treated (right) and non-treated (left) parcels of the same size.

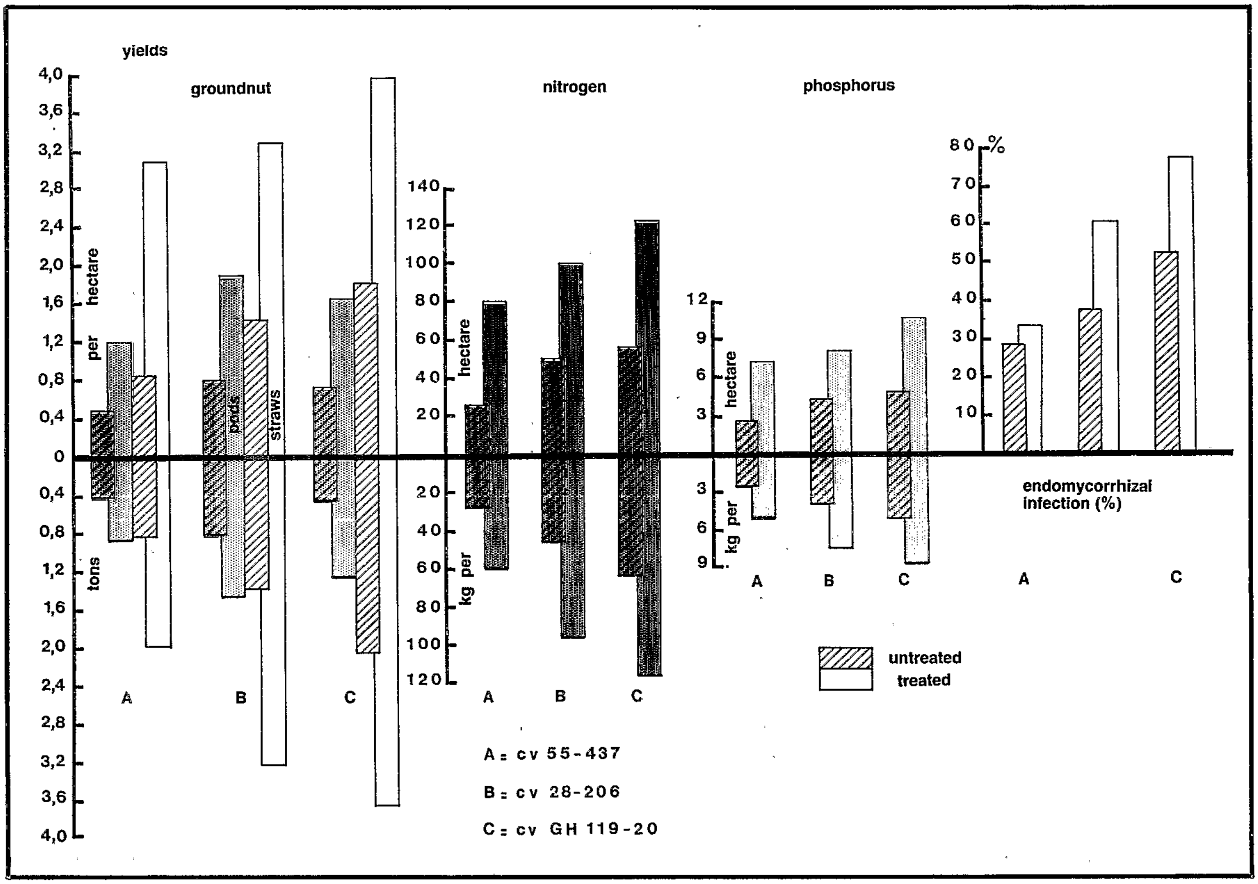


FIG 16

Young millet plants in soil treated one year previously. The limit of treated and non-treated is clearly visible.

◀ **FIG 15**
Experimental plots. Seed (red) and straw (yellow) yield of 3 groundnuts varieties in treated (solid bars) and non-treated (broken bars) soil. First (above horizontal line) and second (below horizontal line) year yields are shown. Also are given plant nitrogen (green) and phosphorus (blue) levels and levels of endomycorrhizal infestion (white).

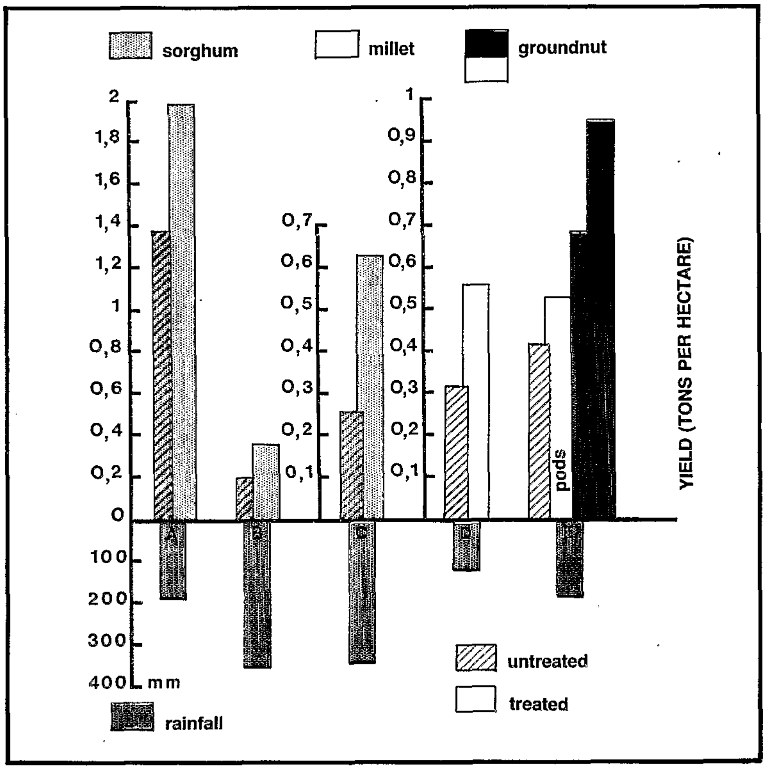


FIG 17 ▶
Residual effect of large scale nematicide treatment on sorghum (red), millet (white) and groundnut (seed : yellow; straw : green). Treated plots (solid bars) non-treated (broken bars) A, B, C : treated one year previously; D, E : treated two years previously.

an important aspect of the value of soil fumigation in the bassin arachidier. Population samples in some fields, eight years following treatment, revealed no reestablishment by ***S. cavenessi*** and, consequently, residual effects of soil fumigation may be anticipated for a considerable time.

ADDITIONAL TREATMENT EFFECTS

Several other significant consequences of soil fumigation in this region are :

- Groundnuts mature earlier in fumigated compared with non-fumigated fields. This may leed to revision of varieties (90, 110 and 120 day cycles) recommended in regions with various annual rainfall patterns. Revision of recommended millet and sorghum varieties may also be desirable.

- Optimum sowing densities may be reduced because of greater size attained by plants grown in fumigated soil. This will reduce production costs as well as the land surface necessary to provide certified seed.

- Fertilizer recommendations may alter in response to better groundnut utilization of atmospheric nitrogen and free phosphorus in fumigated fields.

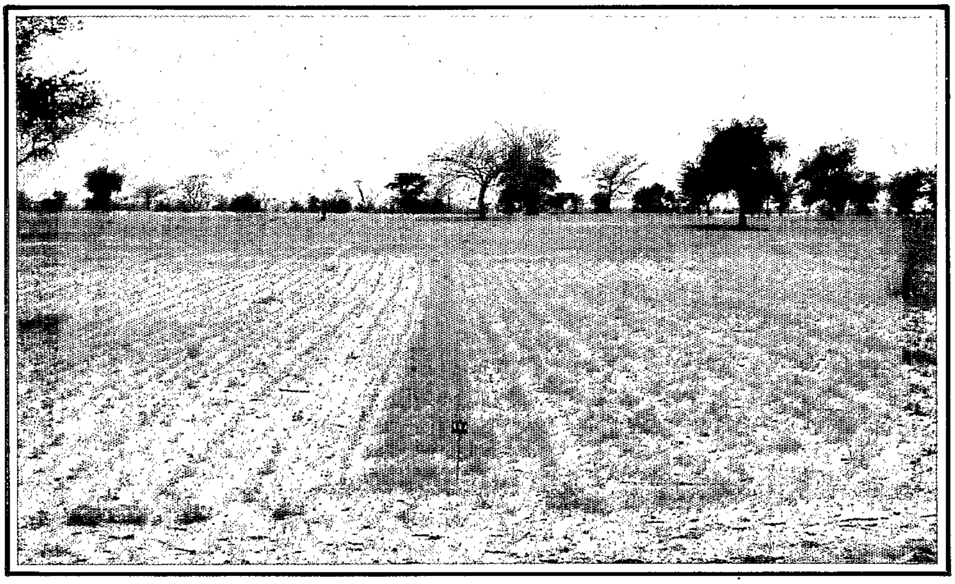


FIG 18
Herbicidal effect of DBCP. Treated (left) and non-treated (right).

- A nematicide-fertilizer mixture may prove profitable since granular fertilizers are not always well distributed in the root profile by the irregular rainfall in the bassin arachidier.
- DBCP has a mild herbicidal effect which imparts to groundnuts a competetive advantage over early-season weed growth (fig. 18).
- Measurement of insect and fungal soil population levels and species composition have detected no effects of DBCP treatment.

CONCLUSION

The results summarized herein represent nearly 10 years of group research. Soil fumigation techniques for this region can undoubtedly be improved and work is progressing to this end.

Nevertheless, enough information is presently available to permit a transformation of crop production in Senegal's bassin arachidier.

Low crop production in the region is not merely the result of intensified drought conditions that have been experienced in recent years. Laboratory research, crop response to soil fumigation and, especially, the long term residual effects following fumigation demonstrate the influence of nematodes in reducing yields of both cash (groundnut) and food (millet and sorghum) crops and consequently the living standards of a great proportion of Senegal's people.

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