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EFFECT OF NITROGEN FERTILIZATION (UREA) AND OF ORGANIC AMENDMENT (COMPOST) ON THE STABILIZATION OF SOIL ORGANIC MATTER IN A MILLET MONOCULTURE IN SEMI-ARID TROPICAL CONDITIONS

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EFFECT OF NITROGEN FERTILIZATION (UREA) AND OF ORGANIC AMENDMENT (COMPOST) ON THE STABILIZATION OF SOIL ORGANIC MATTER IN A MILLET MONOCULTURE IN SEMI-ARID TROPICAL CONDITIONS

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SUMMARY

Technique used to increase the cereal production must satisfy two objectives : on one hand, improvement of yield and nutritional value and, on the other, maintenance of soil fertility. Taking into account both aims, an four-year experiment was carried out at Bambey (Senegal). Organic manuring (composted millet straw) and mineral fertilization including nitrogen were supplied every year to a culture of millet grown on the same sandy soil.

The soil productivity aspects (yields, nutritional value) were presented by GANRY (1977), and the soil organic matter stabilization study is the subject of this paper.

A very simple fractionation method carried out on large amounts of soil made it possible to separate the soil organic matter into three parts :

- plant residues of size larger than 2 mm (ML1 fraction),
- plant residues of size smaller than 2 mm (ML2 fraction),
- humified organic matter (FL fraction).

The authors show that it was not possible to improve the stock of soil organic matter unless organic manuring and nitrogen fertilization were supplied together. The increase in carbon level is due to the carbon contained in the ML2 and FL fractions and varies in the proportion to the quantity of nitrogen fertilizer.

In absence of nitrogen fertilization, compost supplied alone did nc result in an improvement of soil organic matter content.

In absence of organic amendment and whatever the supply of nitroger fertilizer no increase in soil organic matter content was observed.

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ORSTOM : Office de la Recherche Scientifique et Technique Outre-Mer.
IRAT : Institut de Recherches Agronomiques Tropicales.
CNRA : Centre National de la Recherche Agronomique.
ISRA : Institut Sénégalais de Recherches Agricoles.

RESUME

Les techniques mises en oeuvre pour augmenter la productivité céréalière doivent satisfaire à deux objectifs : amélioration du rendement et de la valeur nutritionnelle d'une part, et maintien de la fertilité du sol, d'autre part. Répondant à ce double souci, une expérimentation sur quatre années, consistant à associer amendement organique (paille du mil compostée) et fumure azotée et minérale, a été réalisée, en monoculture du mil, sur sol sableux, au SENEGAL (BAMBEY).

Les aspects concernant la productivité (rendements, valeur nutritionnelle) ont été présentés par GANRY (1977), et l'étude de la stabilisation de la matière organique du sol fait l'objet de ce travail.

Un fractionnement très simple, et portant sur de grosses quantités de sol, permet de séparer la matière organique en trois fractions :

- les résidus végétaux de taille supérieure à 2 mm (fraction ML1),
- les résidus végétaux de taille inférieure à 2 mm (fraction ML2),
- la matière organique humifiée (fraction FL).

Les auteurs montrent qu'il n'est possible d'améliorer le stock organique du sol qu'en associant amendement organique et fumure azotée. L'augmentation des teneurs en carbone est due à celle des fractions ML2 et FL et varie proportionnellement à la dose d'engrais azoté.

En l'absence de fertilisation minérale, l'apport de compost seul ne permet pas l'amélioration des teneurs en matière organique du sol.

En l'absence de compost, et quelle que soit la dose d'engrais azoté apportée, aucune amélioration des teneurs en matière organique du sol n'est observée.

1/ - GENERAL PRESENTATION OF THE INVESTIGATION

The dramatic degradation of soils in the dry tropical zone, cons cutive to the clearence of natural vegetation and the introduction of cultiv is well known*. The maintenance and/or a lasting improvement of the fertili of these soils is an essential aim of tropical agronomic research. Researche undertaken for some years by IRAT in order to reach this objective (PICHOT, have shown the importance of organic matter status in maintaining soil fert lity and have led to the search for techniques aiming at increasing and stab lizing the organic stock of cultivated soils in the tropics.

In the specific case of sandy soils, organic matter is a key fac for improving soil biological and physical properties, its reserve of nutrie thus increasing the yield more than chemical fertilizers.

With this in mind, IRAT set up in various African countries (in 1971, in Senegal) a series of experiments called "Experiment of the Spec Role of Organic matter", which consisted in the application of increasing amounts of nitrogen with or without organic matter amendment.

We are reporting here the results of experiments set up at the CNRA of Bambey (ISRA, Senegal) in order to elucidate the effects of the appl cation of millet straw compost, in presence of different doses of nitrogen fertilizer, on a continuous culture of millet for four successive years.

One part of this study (GANRY, 1977) will deal with the soil productivity, both from the quantitative stand point (yields) and from the qualitative one (nutritive aspect of the crops). By this means one could hopefully evaluate the immediate and less immediate effects of applied cultivation techniques.

In this part, the balance of soil organic matter will be conside after four years of experiment, and thus tackle the middle term effects of this fertilization.

2/ - MATERIAL AND METHODS

The experimentation was conducted at the CNRA of Bambey on a slightly leached ferruginous tropical soil (Dior soil). The annual average pluviometry between 1972 and 1975 had been 430 mm. The test plant under cons deration is millet (Pennisetum typhoïdes Hubb and Staff). From 1972 to 1974, Souna III was used, this millet being characterized by its traditional high structure. In 1975, a newly selected millet was used which is characterized by a shorter structure, and a shorter cycle (75 days from sowing to harvest instead of 90 days). Treatments were as follows : 0, 30, 90, 120, 150 kg N/h in presence or in absence of millet straw compost.

The compost was made in a pit from finely ground millet straw (residues of about 2-5 cm in lenght). Beds of damp straw were interlayed between thin beds of manure, which served as inoculum. Composting lasted fro 4 to 6 months and the C/N ratio decreased from about 35 to 20.

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* : In Senegal, see : BOUYER (1959), DOMMERGUES (1956), FAUCK et all (1969) FELLER and MILLEVILLE (1976), SIBAND (1974).

The compost, brought each year at the end of the cycle (October) was buried 20 cm deep together with the residues of the previous crop (millet stalks not exported) at the rate of 11.0, 15.0, 9.3 and 9.3 t/ha (dry matter) for the years 1971, 1972, 1973, 1974 respectively.

The experiment comprised elementary plots of 6 x 20 m, arranged in blocks, subdivided into two sub-plots A and S (with or without compost) with six replications*. The elements P, K, and S were brought each year at the rate of 100 kg/ha of P_2O_5 and K_2O and 10 kg/ha of S. Oligo-elements, in the form of nutramine, were applied at the rate of 5 kg/ha in the first year (1972). Nitrogen was applied as urea three times during the course of the growth cycle (1/5 at sowing, 2/5 at thinning (10e - 15e day) and 2/5 during stem elongation).

For this part of the study soil samples were taken from sub-plots which received compost and different amounts of nitrogen fertilizer. Their principal characteristics are summarized in the table below :

Treatment (*)	Mineral maintenance fertilizer (P,K,S)	Nitrogen fertilizer kg/ha	Compost
1 A	No	0	Yes
1 S	Yes	0	No
2 A	Yes	0	Yes
2 S	Yes	0	No
4 A	Yes	60	Yes
6 A	Yes	120	Yes
7 A	Yes	150	Yes
7 S	Yes	150	No

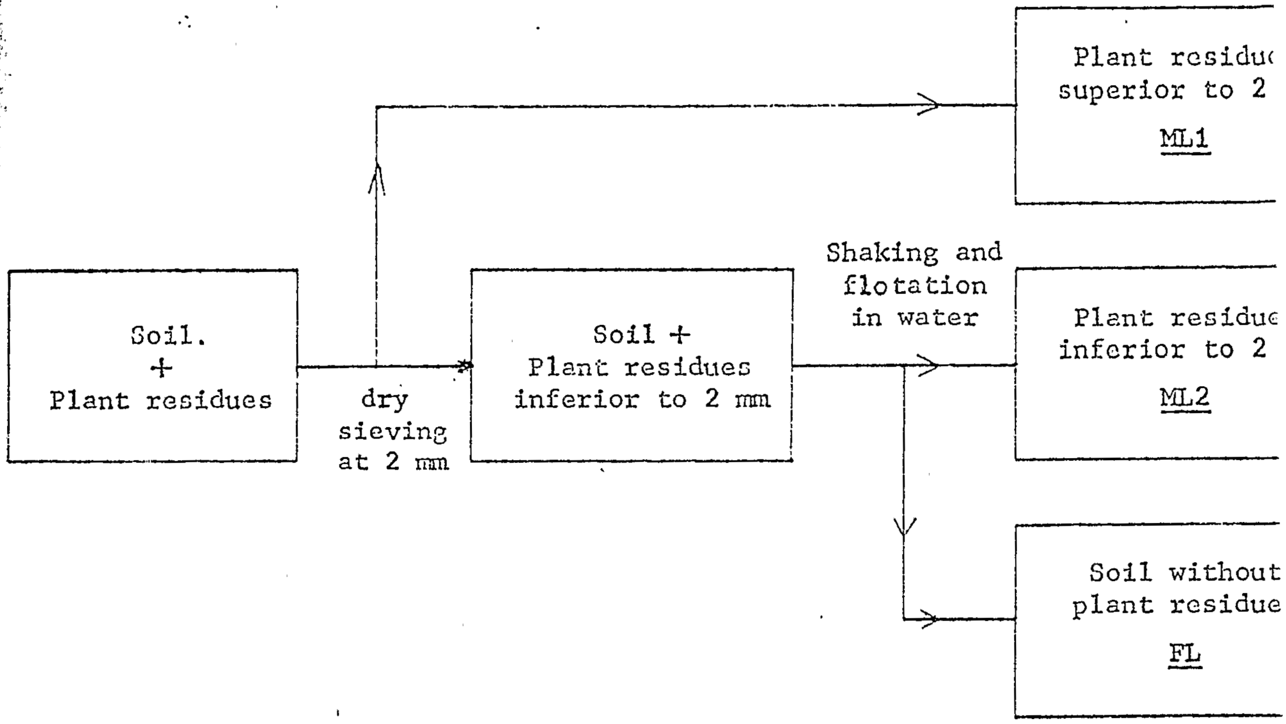
In December 1976, when this work was carried out, no compost was added during the ploughing following the harvest, so that the samples examined here make possible the comparison of four years of cropping with, and without addition of compost.

Because of the technique of deep placement used (ploughing), the distribution of the organic matter in the soil is very heterogeneous, and a preliminary statistical study to establish the size of the samples necessary for each treatment was carried out. This has shown that 60 spade samples (about 240 kg of soil) at a depth of approximately 20 cm, are needed to estimate the weight of plant residues of more than 2 mm lenght (ML1 fraction) with an average standard error of approximately 16 % (P = 0,05).

* : - A indicates with compost,
- S indicates without compost.

Each soil sample is divided into :

- plant residues of a size greater than 2 mm (ML1 fraction),
- plant residues of a size smaller than 2 mm (ML2 fraction),
- soil cleared of ML1 and ML2 fractions and called FL fraction (organo-mineral fraction or "linked-fraction").



The results, for each organic fraction, are expressed in C ‰ of the weigh of the soil.
Technical details are presented in addendum.

3/ - RESULTS

Fig. 1 shows the actual variations of the carbon content and fi the variations of the different fractions of the treatments with compost ir relation to the total carbon content of the treatments without compost (cor

2.1 - Relative proportions of the different fractions

ML1 fractions represent only 2-3 % of the total carbon as compa to 20-35 % for ML2 fractions and 60-80 % for FL fractions.

Although the addition of organic matter was made in the form of residues of size superior to 2 mm (ML1)*, these particles disappeared almos completely during the rainy season, and contributed at their initial size, only very little to the carbon balance.

2.2 - Evaluation of the different fractions as a function of the trea

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* : In the compost used organic residues of size greater than 2 mm represen 90 % of the total organic matter and only 10 % is present in form of organi particles of size smaller than 2 mm.

Observation of fig. 1 and 2 shows that :

1) - For the controls without compost, carbon amount of the different fractions remained constant whatever the amounts of nitrogen and mineral fertilizer added (treatments 1S, 2S, 7S).

2) - The compost enriched the soil in carbon in all cases except for treatment 1A where decreases of the FL fraction and the total carbon CT as compared to the control were observed (fig. 2).

3) - We noted a marked effect of nitrogen on the ML2 and FL fractions of the treatments with compost. The variation of the carbon was proportionate to the amount of nitrogen applied. The increase went up to 110 % for the amount of 150 kg/ha and represented 100 % for the amount 90 kg N/ha which is often used in fertility studies for the soils of CNRA of Bambey. On the other hand, there was no variation for the ML1 fraction and the increase in relation to the control was very slight.

4) - Even without nitrogen, the compost added to the maintenance mineral fertilizer (P, K, S) caused an increase of 25 % of the total carbon (see fig. 2, treatment 2A). However the addition of compost in the absence of mineral and nitrogen fertilizer (see fig. 2, treatment 1A) induced a notable decrease of the FL fraction and hence of the total carbon (ML1 and ML2 fractions remained more or less constant).

4/ - DISCUSSION AND CONCLUSIONS

The following facts may be deduced from the results as a whole :

1) - Within the framework of this experiment, the improvement of the soil organic matter appeared to require an organic amendment (in this case compost). Nevertheless, this must be combined at least with a maintenance mineral fertilizer, otherwise the opposite effect to that expected is observed, i.e. a decrease of the total carbon.

2) - The enrichment in carbon seemed to increase when the deep placement was combined with large additions of nitrogen. Several hypotheses may be considered in explanation of this result, in particular :

a) - The nutritional role of the compost

In the absence of nitrogen and of mineral fertilizer, the compost acts as a reserve of nutritive elements first for the microflora and second for the plant*. Its humification role is then negative (treatment 1A) or slight (treatment 2A). On the other hand, in the presence of high mineral additions, the nitrogen requirements of the microflora are partly met by the fertilizer and the evolutionary process of the compost is then directed towards humification rather then towards mineralization.

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* : The compost used contains 1.2 % of nitrogen and the deep placement of 10 t/ha, corresponds to a nitrogen amendment of about 120 kg N/ha. However the compost contributes only little in the absence of nitrogen fertilizer, to the nutrition of the plant (SIBAND and GANRY, 1976) and consequently only the microbial nutrition has here to be taken into consideration.

b) - The protective role of nitrogen

The presence of nitrogen allows the synthesis of stable humic compounds on the surface or even within the plant residues, which may have a protective effect in relation to the mineralizing action of the microflora.

c) - The increase of the root system

The simultaneous presence of nitrogen and of compost increase plant growth, in particular that of the root, and thus indirectly permits an increase of organic matter in the soil in the form of root residues.

3) - The fractions which benefit are the two fractions most humified ML2 and FL since the fraction ML1 hardly appears in the carbon balance.

These preliminary results, relatively spectacular (multiplication by two of the carbon levels for high amounts of nitrogen), in tropical conditions where the mineralization processes are intense, lead to at least three questions.

1. - For a given agricultural practice (nature of vegetation and agricultural techniques) how stable is the newly formed organic matter ? *In other words, what is the time necessary for the return to the original organic level if all organic amendments are stopped ?*

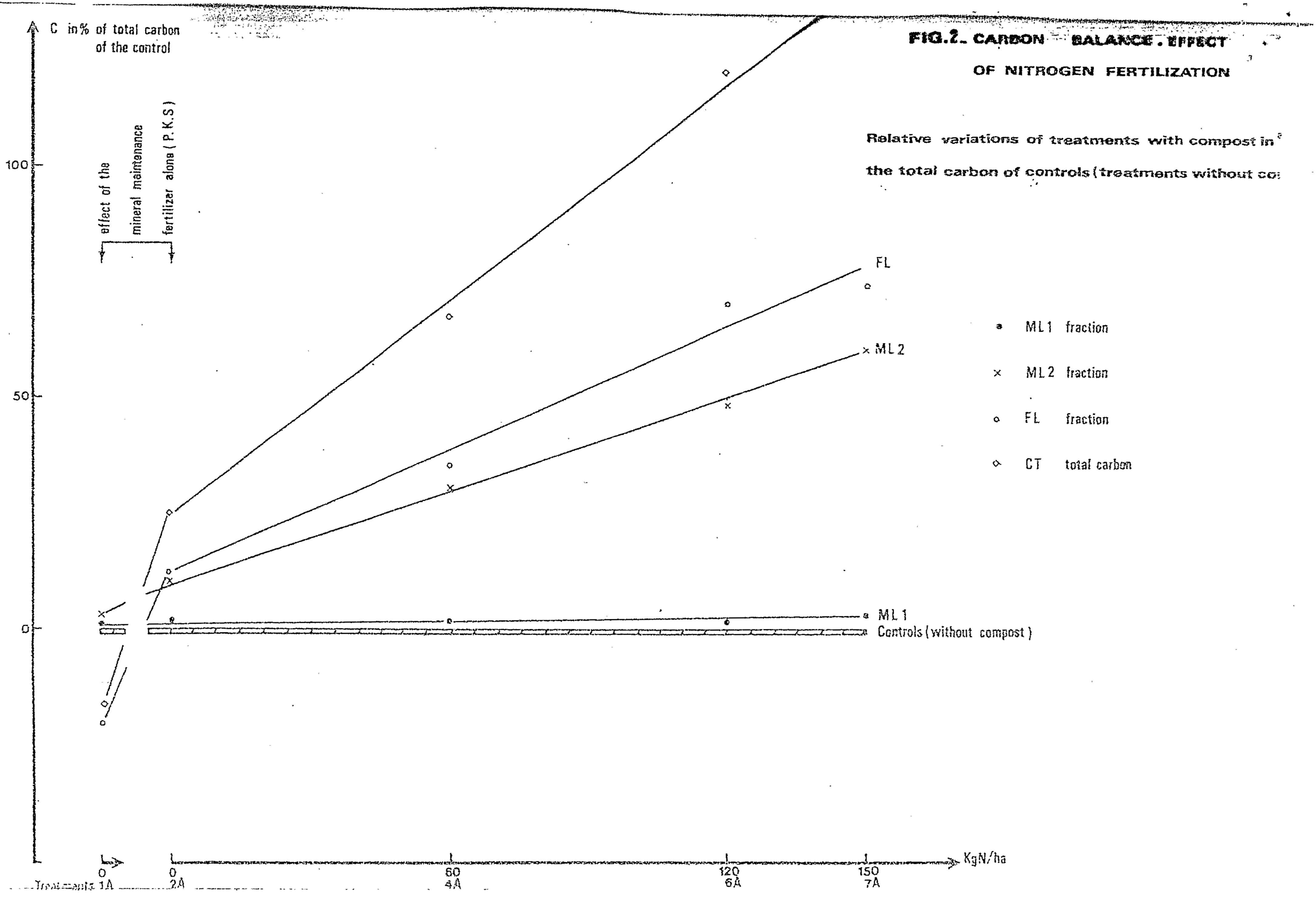
2. - What is the optimum solution of $\frac{\Delta M.O.}{\Delta t} = f(C,N)$, which allows to raise the level of organic matter in a soil from its present point A to a given point B previously defined through economic and/or agronomic considerations.

3. - Can the same aims be attained with other organic residues besides compost. Also, what is the role of these residues on the evolutionary processes of organic matter ?

The next stage of this study should make it possible to reply, at least partially, to these questions.

FIG.2. CARBON BALANCE. EFFECT OF NITROGEN FERTILIZATION

Relative variations of treatments with compost in the total carbon of controls (treatments without co



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A D D E N D U M

FRACTIONATION OF SOIL ORGANIC MATTER

Plant residues of size larger than 2 mm : ML1 fraction (free organic matter

The whole soil sample, approximately 240 kg, is air-dried and passed through a 2 mm sieve. The fraction remaining on the sieve is then cleared of sand by flotation in water, dried at 50° for four days, weighed, then finely ground (ML1 fraction).

The soil humidity is determined by oven-drying at 105° for 24 hou and the ash content by oven-calcination at 750° for 4 hours.

The carbon content is measured in a carmograph and expressed as a thousandth part of the weight of the soil.

Plant residues of size smaller than 2 mm : ML2 fraction (free organic matte

2 kg of soil sieved at 2 mm and cleared of ML1 fraction were decanted by successive fractions in about 10 litres of water. The plant resid of size smaller than 2 mm were then separated by flotation (*), dried at 50° for four days, then finely ground (ML2 fraction). They are then treated in the same way as ML1.

Humified fraction of organic matter : "fraction liée FL"

The soil residue after separation in water of ML2 (**) is dried, ground at 0.5 mm and, on this fraction (FL) the carbon content is determined.

(*) - By shaking the soil under water and by successive decantations, it is possible, in these sandy soils, to recuperate almost the whole of the plant residues inferior to 2 mm length, even if their density is greater than 1.

(**) - When ML2 is separated, the clay fraction remaining in suspension in the water is floculated by addition of HCL at 1/2 up to 2.0. After decantation, centrifugation and washing in water, this fraction is recuperated and added to the soil residue.