MANAGEMENT OF BANANA NITROGEN FERTILIZATION: TAKING INTO ACCOUNT NITROGEN FROM ORGANIC ORIGIN

RAISONNEMENT DE LA FERTILISATION AZOTEE SOUS CULTURE BANANIERE : PRISE EN COMPTE DE L'AZOTE D'ORIGINE ORGANIQUE

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SUMMARY

Strategies for banana nitrogen fertilization rarely consider nitrogen supply by soil organic matter or crop residues mineralization. Results of a trial comparing different levels of nitrogen fertilization showed no yield increase above a nitrogen fertilization level markedly lower than recommendations based on crop nitrogen uptake. This result suggests that, besides fertilizers, others sources of nitrogen that are not taken into account in conventional program of fertilization are available for banana nutrition. Nitrogen amounts released from soil organic matter mineralization depend on soil characteristics. In Caribbean high altitude andosols e.g., soil organic matter mineralization covers an important part of banana nitrogen requirements. The SIMBA model simulates the dynamics of banana nitrogen uptake and crop residues return. It can be used to schedule fertilizer applications in order to limit leaching risks while maintaining in the soil sufficient amount of available nitrogen to meet plant requirements.

Keywords: management, N supply, requirements.

RESUME

Les règles de fertilisation azotée en bananeraie prennent rarement en compte l'azote fourni par la minéralisation de la matière organique du sol ou des résidus de culture. Les résultats d'une expérimentation comparant différentes doses d'azote montrent qu'à partir d'un niveau de fertilisation azotée inférieure aux recommandations établies sur la base des prélèvements par la culture il n'y a plus d'augmentation du rendement. Ceci suggère que l'azote des engrais n'est pas la seule source d'azote pour le bananier et l'existence d'une offre d'azote non prise en compte dans la fertilisation conventionnelle. La matière organique du sol fourni des quantités d'azote minéral très variables en fonction du type de sol. Dans les andosols d'altitude des Antilles, les quantités d'azote issues de la minéralisation de la matière organique du sol couvrent une partie importante des besoins du bananier. L'utilisation d'un modèle simulant la dynamique des restitutions organiques et de l'absorption d'azote par le bananier (SIMBA) permet de définir des stratégies de fertilisation garantissant la satisfaction des besoins du bananier tout en limitant les pertes d'azote par lessivage.

INTRODUCTION

Mineral nitrogen available for banana nutrition originates mainly from (i) soil organic matter mineralization, (ii) crop residues mineralization and (iii) fertilization. Nitrogen fertilization management aims at adjusting fertilizer applications in such a way that supply of nitrogen fit with crop demand. The objective is to minimize the waste of nitrogen due to leaching or run-off. Concerning banana crop, fertilization management faces two main difficulties. The first difficulty is the lack of sufficient knowledge concerning organic matter mineralization in tropical conditions. There are especially few references about degradation rate of crop residues in function of climatic conditions or about organic matter protection by components of tropical soils such as allophane, Al or Fe. The second difficulty is due to the progressive loss of synchronization of the bananas with time making difficult to fit fertilizer applications with the variation of banana demand. These difficulties lead, in order to secure yield, to recommend nitrogen fertilizer amounts that widely exceed nitrogen output by harvesting.

Experimentation was carried out to study the influence of different levels of nitrogen fertilization on growth and nitrogen nutrition of banana. To assess soil nitrogen availability, we measured the uptake of nitrogen by banana and nitrogen mineralization in 2 liters pots containing different volcanic ash soils from Guadeloupe. The banana crop simulation model SIMBA was calibrated and tested to assist nitrogen fertilization management in order to reduce waste of nitrogen by leaching while meeting banana demand.

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MATERIAL AND METHODS:

. Nitrogen fertilization experimentation

Five treatments of nitrogen fertilization were experimented in a banana plot of the CIRAD experimental station of Neufchateau in Guadeloupe (altitude 250 m, annual rainfall 3500 mm, andosol derived from volcanic ash).
The following treatments were applied:

- T 0: 20 kg N/ ha /an
- T 1: 120 kg N / ha / an
- T 2: 220 kg N / ha / an
- T 3: 320 kg N / ha/ an
- T 4: 420 kg N / ha / an

In all treatments, the nitrogen supply was split in 12 monthly applications.
Each treatment was replicated on five 500 m^2 elementary plots.
Between planting and flowering, the following measurements were carried out monthly on 10 bananas per elementary plot:

. Banana circumference
. Soil mineral nitrogen content in 0-20 cm layer
. Chlorophyll content (measurement by chlorophyll-meter SPAD-502) and nitrogen content of the second leaf of the banana.

At flowering time, number of fruits on the bunch and fresh weight of the whole banana were determined
The amount of rainfall percolating through the soil or running off is calculated monthly from the following soil water balance equation:

Drainage = Rainfall – □ Soil water storage - Crop Evapotranspiration

. Determination of soil organic nitrogen availability

Soil samples were collected in the 0-20 cm layer of 12 banana plots of Guadeloupe selected on a soil topo-sequence Andosol => Nitisol derived from volcanic ash ranging from 0 to 450 m. Four plots were selected on the Neufchateau station which is located in the middle of the topo-sequence.
Soil organic nitrogen availability was determined measuring N uptake and N mineralization in 2 liters pots planted with bananas during a two months experiment.

. Functioning of the SIMBA Model

The SIMBA model (Tixier *et al*., 2004) simulates the progressive loss of synchronization of the development stages in a banana field and especially the spreading of the harvesting periods and of the crop residues return over successive crop cycles.
We added to SIMBA a sub-model « Nitrogen - organic matter » in order to evaluate, over successive crop cycles, variations in N uptake, N leaching and N supply by crop residues and soil organic matter mineralization.
The «Nitrogen - organic matter» sub-model operated as follows:
- Nitrogen leaching was calculated considering that the nitrogen concentration in water was proportional to the soil mineral nitrogen content. The soil mineral nitrogen contents measured during the nitrogen fertilization experimentation described above were used for model calibration.
- The nitrogen amount supplied by soil organic matter and crop residues mineralization was calculated according to Hénin and Dupuis (1945). The coefficient of crop residues mineralization (K1) was determined from findings of Godefroy (1974). This author reported that, after one year, 55 % of nitrogen from banana crop residues remains in soil organic matter while the other part is mineralized.
The coefficient of mineralization of soil organic matter (K2) was evaluated from results of the nitrogen availability experiment presented above.
- Banana N uptake was calculated from dry matter production considering that N content of the whole plant was 1% (Turner 1990).

RESULTS AND DISCUSSION

Experimental results

For the plant crop, we did not observe any significant difference in bananas growth (figure 1) and in yield indicators (fruits number, flowering date) between the N fertilization treatments.

Nevertheless, chlorophyll and nitrogen content of the second leave were significantly different between the N fertilization treatments (figures 2 and 3). These indicators of N nutrition seem more sensitive than yield indicators to the level of N fertilization.

At planting, soil mineral nitrogen contents were high probably because of previous crop residues mineralization (non-presented). After planting, nitrogen contents exhibited high variations apparently due to leaching. We observed a close relationship between the waste of nitrogen per millimeter of water evacuated by drainage and the soil mineral nitrogen content (figure 4): the higher the soil mineral nitrogen content, the higher was the waste of N by leaching.

Banana N uptake from planting to flowering, calculated from the weight of the whole banana, was about 230 kg N/ha whatever the nitrogen fertilization treatment. Nitrogen supply by fertilizer from planting to flowering was however 10, 60, 110, 160, and 210 kg N /ha in the treatments T0, T1, T2, T3 and T4. Nitrogen fertilization was thus below banana N uptake in all treatments. These results suggest a high contribution to banana nutrition of nitrogen originating from previous crop residues and soil organic matter mineralization.

The measurements of nitrogen uptake and mineralization in 2 liters pots showed that the amounts of nitrogen mineralized in the 0-20 cm layer for two months ranged from 30 kg to 120 kg N/ha, depending on soil type and soil organic matter content (figure 5).

We notice that the andosol, despite higher organic matter content, released the same amount of mineral nitrogen as Nitisols. The constituents of Andosol (allophane, Al, Fe) are known to protect organic matter against microbial degradation and to reduce the availability of organic nitrogen (Dahlgren et al, 2004; Dorel et al, 2006). However, the amount of nitrogen mineralized in the perhydrated andosol from the top of the topo-sequence, which exhibited the highest organic matter content, was three times greater than in the nitisol or in the andosol located at lower altitude. In the soil of Neufchateau, where was performed the N fertilization experimentation, organic matter released about 40 kg mineral N /ha for two months. This amount is the half of the mean nitrogen uptake observed for two months during the nitrogen fertilization experimentation.

These results explain the lack of effect of the fertilization treatments on the growth and on the yield of the plant crop. The increase of nitrogen leaching proportionally to the soil mineral nitrogen content, the supply of high amount of mineral nitrogen by previous crop residues and soil organic matter mineralization have certainly reduce the difference of available nitrogen between the five fertilization treatments.

Simulation with the SIMBA model

Our experimental results enabled to parameterize the sub-model « Nitrogen-Organic Mattter » of SIMBA.

The model was used to predict the variations of soil mineral nitrogen and the terms of the nitrogen balance (inputs and outputs) over successive crop cycles. The amount of nitrogen supply had only a slight influence on soil mineral nitrogen dynamics (figure 6). Soil mineral nitrogen exhibited high variations during the first crop cycles. Soil nitrogen decreased drastically when high plant demand and intense leaching occur at the same period (figure 7). As soon as nitrogen outputs (plant uptake, leaching) became lower, organic matter mineralization and fertilizer supply contributed to increase soil mineral nitrogen.

Changes of soil mineral nitrogen tended to lessen with time. After several crop cycles, we observed a progressive spreading of nitrogen uptake and nitrogen mineralization due to the loss of synchronization of the stages of development in the banana plot.

The method proposed by Godefroy (1983) to manage banana fertilisation take into account the waste of nitrogen by leaching and recommends applying a nitrogen fertilizer when the cumulated rainfall since the last fertilizer application reach a critical threshold. This method was designed for asynchronous banana field with many stages of development present at one time. In that case crop nitrogen demand can be considered as constant all through the year. For the first crop cycles, exhibiting still a synchronization of development between the bananas, fertilization management must take into account the variations of crop nitrogen demand and nitrogen supply by crop residues mineralization. The SIMBA model enables to predict the dynamics of demand and supply of nitrogen in a banana plot.

It can be used to schedule fertilizer applications in order to (i) limit mineral nitrogen accumulation in soil (reduction of leaching risks) and (ii) to maintain sufficient amount of available nitrogen to meet plant requirements

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