Mineralization of two organic fertilizers in organic cotton sustainable cropping systems

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Introduction

Cotton is the most important non-food agricultural product in the world, occupying more than half the area of crops not for food. Cotton crops spread through 1.3% of the surface in Europe and represents 0.5% of agricultural production in the EU, where it is produced mainly in Greece (78%) and Spain (22%). In Andalusia, cotton crops account for 66% of total extensive irrigation crops. Traditionally, cotton-derived industries have been very important in Spain, although activity is currently declining because of competition from Asian countries. Up to 93% of Spanish cotton is produced in Andalusia, where associated industries employ 10000 families and provides around 5% of agricultural production, having a great social and economical impact. Recent EU policies make difficult the maintenance of cotton mainly due variable prices and high costs, leading to a possible disappearance of the crop and, therefore, a loss of EU incentives. In Spain, the largest concentration of cotton crops is in the Guadalquivir basin, where farmers are forced to find alternatives to increase yields and reduce costs in the short term. A possible solution to this problem would be organic production, which would reduce costs and increase prices. One of the most important factors to be considered is an optimal and sustainable use of N fertilizers. So, the aim of this research is to analyze nutrient dynamics after organic fertilization in the study area, with these objectives:

1. to determine the mineralization rate of two fertilizers,
2. to establish the peak release of ammonium, nitrate and nitrogen, studying the optimal timing of fertilizer application, and
3. to establish an optimal dose of fertilizers.

Methods

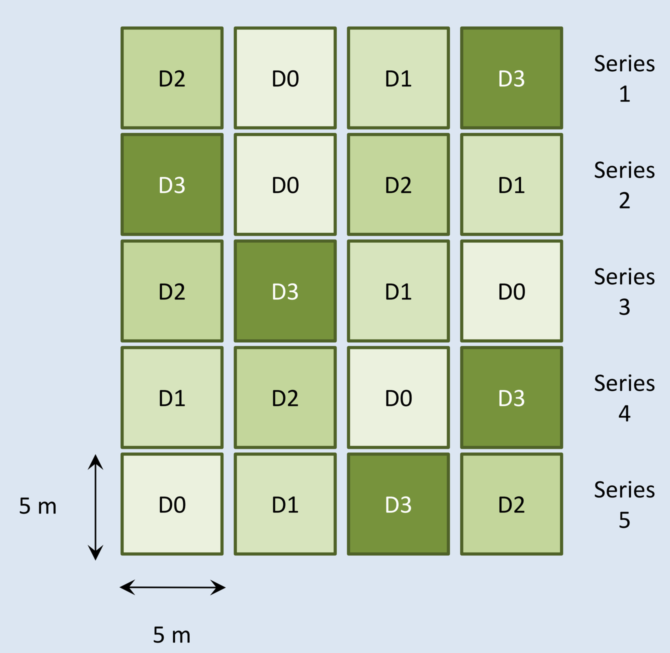

Fig. 1. Design of the field experiment, with 5 replicated series (rows) of 4 doses (D0-D3).

Experimental design

The study area is located in an experimental farm in Las Cabezas de San Juan (Sevilla, Southern Spain).

Fertilizers were applied by by hand (2 April) according to a randomized block design with 4 treatments and 5 replicates (sets). Two fertilizers were used in twin experiments: Agrimartín FE-BIOLÓGICO (sheep manure and plant waste, in powder or pellets) and Abonatur (composted plant debris, powder). At each case, fertilizer doses used for each treatment was 0 (D0), 50 (D1), 100 (D2), and 150 kg ha^{-1} N (D3).

The experimental area was divided in 20 plots (5 sets of 4 treatments), as shown in Figure 1. After plant emergence, 15 PVC tubes (30 cm long and 6 cm in diameter) were inserted into the soil at each plot on May 20th 2008, in order to isolate the soil sample from roots and control mineralization of fertilizer without external interference. Herbs born into the tubes were removed by hand weekly during the first month. Three soil samples were collected monthly at each plot between June and October 2008 (M1-M5), and transported to the laboratory in plastic bags. Samples were air-dried and sieved (2 mm) for soil analysis.

Fig. 2. Seeding labours before the field experiment.

Fig. 4. Distribution of tubes before being fixed (A) and details of tubes arranged along furrows in different development stages (B and C).

Fig. 3 Spray irrigation during plant nascence (A) and furrow irrigation during the experiment (B).

Soil analysis

Nitrogen forms were monthly analyzed between June and eptemberanalyzed: NO_3^- and NH_4^+, using a Thermo-UNICAM UV2 unit, and total N, using a LECO CNS-2000 analyzer.

Other soil analysis (not studied here) were organic carbon content (Walkley-Black method), pH, electrical conductivity determinations, total N and C (LECO CNS-2000 analyzer), exchangeable cations and CEC, and main nutrients: Na, K, Mg, Ca, Fe, Mn, Cu, Zn and P-Olsen.

Results

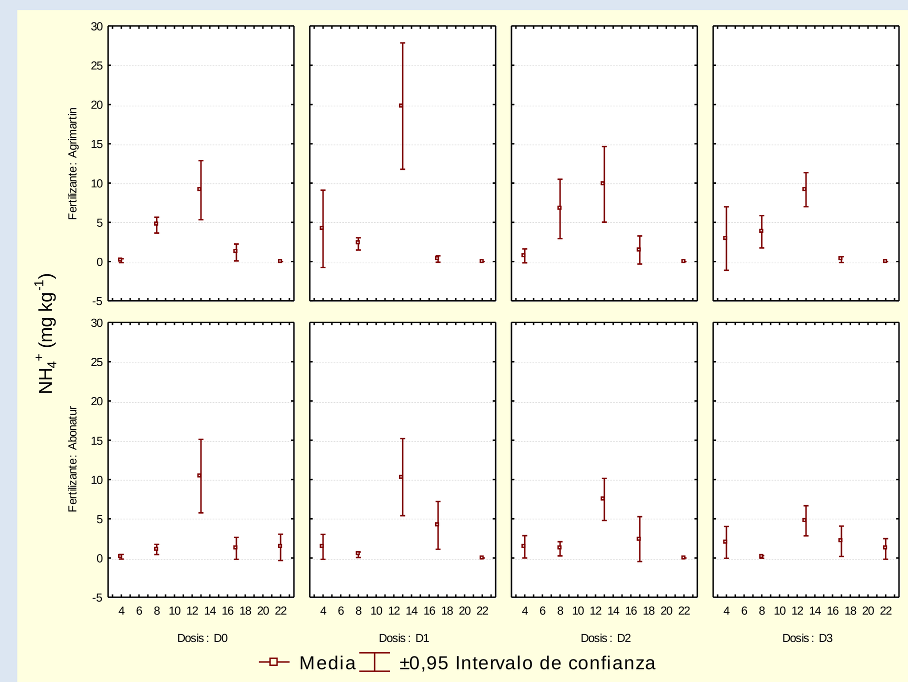

Fig. 5. Evolution of ammonium concentrations in soil for different doses (D0-D3) and fertilizer (Agrimartín and Abonatur).

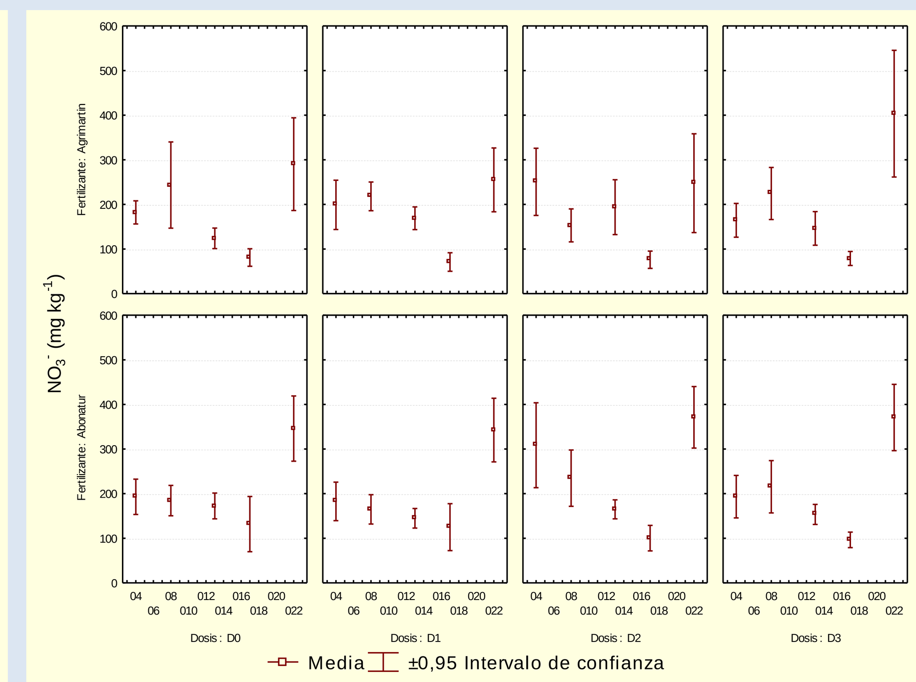

Fig. 6. Evolution of nitrate concentrations in soil for different doses (D0-D3) and fertilizer (Agrimartín and Abonatur).

Ammonium. Initial ammonium content in soils are influenced by residual ammonia, while mineralization has barely begun. Irrigation during July and August accelerated ammonification, leading to increased contents of NH_4^+ in soil by M3. Due to the clayey soil texture, we assume that ammonium losses during M4 experiment were caused mainly by volatilization and adsorption. Nitrogen added to soil can be transformed quickly into NH_4^+ forms by the action of soil microorganisms, intense under moist conditions and low soil aeration. Ammonium has a short residence period in soil and can be lost by evaporation or leaching, due to its high solubility. Moreover, ammonia can be re-transformed into nitrate when reducing soil conditions disappear.

During the first month, ammonium released by the mineralization of fertilizer varied in a narrow range, between 0.37 mg kg^{-1} of the D0 and 3.59 mg kg^{-1} of the D1, showing no differences between treatments. In July, ammonium content increased for doses D0 and D2, maintaining the same level for doses D1 and D3. The highest value was reached during August, probably due to a decrease in crop uptake rather than an increase in the mineralization of fertilizer.

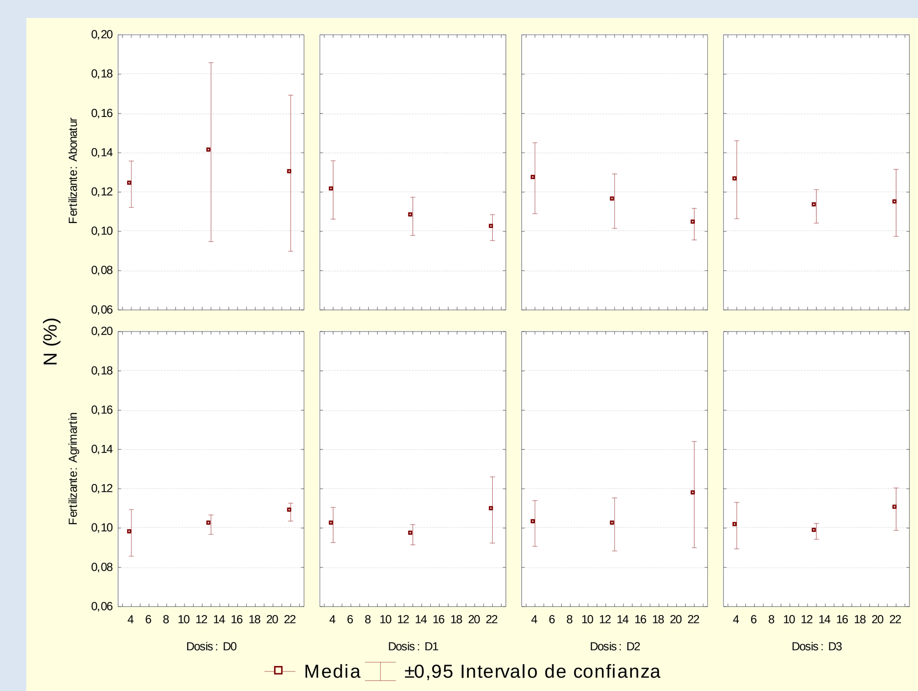

Fig. 7. Evolution of organic nitrogen concentrations in soil for different doses (D0-D3) and fertilizer (Agrimartín and Abonatur).

Aproximately 66% of nutrient requirement occurs during the first two months of crop growth, between bloom and formation of capsules. In September, a decrease in ammonium content was observed for all treatments until the end of the experiment. This behaviour exists even in the control plots, and these results may point to the mineralization of residual soil N from the previous season. Small differences were observed between fertilizers. Higher contents were observed with Agrimartín by M2 and M3, where the crop is actively growing. On the other hand, residual NH_4^+ contents were higher at the end of the experiment.

Nitrate. According to the results, higher doses do not correspond to a higher content of NO_3^- in soil. This may be due to residual NO_3^-. In general, NO_3^- content decreased progressively, but increased abruptly at the end of the experiment, with maximum values for the last month, higher than the initial values, except for D2. Denitrification is a process that occurs preferentially in clayey, poorly aerated and humid soils with a number of microorganisms which are able to use oxygen from nitrate under anaerobic conditions. Other authors have observed that after application of pig slurry, the higher rate of denitrification was measured 14 days after onset of irrigation, when the saturated pore volume was 78%. The intensity of denitrification processes could explain the lack of statistical differences between the values of nitrate in the soil between doses. The nitrate content in soil during the first month of trial showed no significant differences between treatments, due to the low nitrification rate. After irrigation during July and August and the subsequent saturation of the clay soil of the plot, the conditions will favour increased denitrification rates. Another way out of soil nitrate is due to plant uptake. High initial nitrate soil content make difficult to appreciate the effect of treatments. During the last month, when the crop needs decrease, an increase in nitrate content in soil was observed for all treatments, exceeding the needs of growing and denitrification rate, being more notable for the D3. D3 treatment can cause excessive NO_3^-, not useful for the plant, while the D1 and D2 treatments could provide an amount of NO_3^- high enough without extra cost. Agrimartín showed significantly lower contents by M4 and M5 respect to Abonatur, at the end of the experiment. No significant differences were observed between treatments after fertilization with Agrimartín. This may be due to rapid mineralization processes, so that the fraction of soil organic nitrogen would be stable only during a short period of time after its incorporation.

Nitrogen. After Abonatur treatments, organic N content in soil decreased progressively. Only at the end of D3 treatment, the average content increased significantly, as a result of over-fertilization. In the Abonatur experiment, homogeneity of values between doses is in contrast with the amount of added organic matter in the different treatments, since no significant differences were found between the higher doses of fertilizer. The lack of effect on total nitrogen content after different doses could be due to the interference of residual nitrogen from the previous season.

Conclusions

1. There were no significant differences between mean levels of total nitrogen, nitrate, and ammonium among treatments, due to the high initial soil N content. Previous high values of N-fertilizer limited the response of soils to experiments.
2. The content of ammonium showed a peak during M3 for all doses due to reduced crop needs and the mineralization of organic nitrogen.
3. Dose D1 (50 kg ha^{-1} N) is recommended, in order to maintain available nitrogen content, avoiding high cost excess fertilization.
4. Sooner application of fertilizer is recommended, in order to avoid peaks observed when crop needs decrease at the middle of cropping season.
5. After this experiment, Abonatur showed a more efficient behaviour in terms of N efficiency.

Acknowledgements

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