Proc. 17th Intern. Symp. of CIEC, 24-27 Nov. 2008 © NRC (Micronutrient Project), Cairo – Egypt, pp. 285-289 (2008)

EFFECTS OF MINERAL FERTILIZER AND ORGANIC MANAGEMENT ON SOIL NITRATE AND BARLEY PRODUCTION IN SEMI-ARID CONDITIONS

R. González Ponce, C. Lacasta and L. Garcia

Instituto de Ciencias Agrarias, Centro de Ciencias Medioambientales, CSIC, Serrano 115 dpdo. 28006 Madrid, Spain. E-mail: rgponce@ccma.csic.es

Abstract:

In a long-term experiment performed in a semi-arid area of the Province of Toledo (Spain), plots were used over two years to raise barley either continuously with applications of mineral fertiliser (CC) or under three forms of organic management: continuous cultivation with no fertiliser input (CO), barley raised in rotation with a clean fallow period (CF), and barley raised in rotation with vetch (CV).

The CC treatment was associated with higher autumn soil nitrate contents as well as higher and more stable crop yields than the CO treatment. In the CF plots, the summer accumulation of soil nitrate was favoured during the clean fallow year, and was greater than that seen in the CV plots.

Barley productivity in the different treatments followed the order CF > CC > CV > CO. Productivity was related to the soil nitrate content before sowing.

Introduction:

Barley (*Hordeum vulgare* L.) cultivation is common in the semi-arid areas of Spain. The low productivity of this crop in these areas, a consequence of the latters' scant rainfall (300-500 mm per annum), the distribution of this rain over the year, and the low levels of organic matter in the soil, makes crop management of utmost importance if productive and economic sustainability is to be achieved. Certainly, optimising the correct use of water and soil nitrogen, which strongly influence the productivity of these crops, is very important.

Under semi-arid conditions, periods of N accumulation in the soil can be followed by N depletion, depending on the amount of rainfall and crop growth (Westerman et al., 1994). Under such conditions, an increase in cropping frequency requires additional N be supplied if yields are to be sustained and the level of soil organic matter provided by the stubble maintained (Kolberg et al., 1996). Methods such as crop rotation can influence the N dynamics of soil-plant systems, and nitrogen is a key nutrient in improving crop yield. The rotation of cereals with vetch (*Vicia sativa* L.), a leguminous plant with a high N-fixing capacity, leads to greater yields than those achieved with continuous cereal cultivation (El Mejahed, 1993). Generally, a period of clean fallow before crop cultivation is also beneficial in semi-arid areas. This allows water to accumulate in the soil, although this depends on the soil type, the amount of rain that falls, its distribution, and the rate of evaporation. Clean fallow also allows the accumulation of NO_3^--N (nitrate) via the mineralisation of the soil's organic matter and the absence of its consumption by crops or weeds (El Mejahed, 1993; Warren et al., 1997).

Discrepancies exist, however, with respect to the relationship between soil nitrate content and the grain yield of cereals. El Mejahed (1993) reported that wheat yield increased with soil nitrate levels in unfertilised pots, while others report no such relationship whether these levels are measured at the time of sowing (Smika et al., 1969) or over the year (Page and Talibudeen, 1977). Nonetheless, cereal yields are greater under semi-arid conditions when sown after a fallow period than when no such period is allowed, although they are lower than those obtained when sowing after the growth of leguminous plants (López Bellido et al., 2000).

The aim of the present work was to study, under two sets of climatic conditions, the effects of different barley crop management models on soil nitrate content and crop productivity in a semi-arid area characteristic of central Spain.

Materials and Methods:

This long-term experiment, performed in a semi-arid area of the Province of Toledo (Spain), involved plots (dimensions 20 x 20 m; 5 m between plots) that for eight years had been subjected to different types of barley (*Hordeum vulgare* L.) management. Weed infestation of the plots had been scant. The soil was a Haploxeralf; its pH was 6.2, it was poor in organic matter (0.8 %) and other nutrients, and its texture was that of a sandy loam. The performance of these plots was examined over two periods, 2004-2005 and 2005-2006, chosen for the different climatic conditions that then reigned.

One conventional and three organic management models were followed:

- Conventional continuous management (CC) with the application of fertilizer: a pre-sowing application of 300 kg ha^{-1} NPK (15-15-15), and 150 kg N ha^{-1} (ammonium calcium nitrate; 33.5% N) at the start of tillering. Broad leaved weeds were controlled (90%) in post-emergence by applying oxytril (ioxynil 7.5%, mecoprop 37.5%, bromoxynil 7.5%) at a rate of 2 l ha^{-1} (periods 2004-2005 and 2005- 2006).
- Organic management of barley (no use of agro-chemical products):
  - Continuous cropping (CO) (periods 2004-2005 and 2005-2006).
  - Sowing barley (period 2005- 2006) after a clean fallow period (period 2004- 2005) (CF).
  - Sowing barley (in 2005- 2006) after a vetch (*Vicia sativa* L.) crop (for forage) (in 2004- 2005) (CV).

The barley sowing and harvesting dates were 9 December and 22 June in 2004-2005, and 3 December and 18 June in 2005-2006. The vetch sowing and pods harvesting dates were 9 December and 16 May (2004- 2005).

The weight of seeds planted was 100 kg ha^{-1}, both for barley and vetch. Prior to sowing the plots were subjected to ploughing followed by two shallow tillage. During the clean fallow period (30 June 2004 - 5 December 2005) two shallow tillage were also undertaken to facilitate the infiltration of rainwater and to control weeds. At two points – immediately before sowing in November (even when fertilizers had been applied in the previous autumn under the CC conditions) and at the end of tillering in April - four samples were taken of the top 20 cm of soil from each plot. Soil nitrate was then determined colorimetrically after extraction by the traditional Bremner (1965) method. The experiment involved four replicates of each management system.

Results and Discussion:

Table 1 shows that, in both periods, the autumn rainfall was adequate for good initial barley development. However, while the spring rainfall was adequate in 2004-2005 it was low in 2005-2006, too low for good productivity levels to be achieved.

Table 1. Rainfall (mm) in the two periods

Period	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.
2004-2005	136.1	15.9	19.5	62.8	8.8	59.6	91.3	56.1	31.9
2005-2006	54.1	105.5	80.5	6.2	6.8	11.8	13.4	18.6	15.8

Table 2 shows the change in the nitrate content of the surface horizon of the soil in plots under clean fallow, vetch and barley.

In November 2004, the highest soil nitrate values were recorded in the CC treatment, a consequence of the recent application of mineral fertilizer. All of the other plots had lower soil nitrate values (all of which were quite similar); insufficient time had elapsed since June, and there had been insufficient rain, for the mineralisation of the remains of any prior crop, whether barley or vetch.

April 2005 saw strong reductions in the nitrate levels of the soil surface horizon compared to those recorded in November, largely due to the notable amount of rain that fell between the end of March and early April. This reduction was very noticeable in the CF plot, but even greater in the plots carrying crops (barley or vetch), a consequence of the latters' uptake of this nutrient.

Table 2. Mean soil nitrate content (0-20 cm) and barley yields for each type of barley crop management

Crop management	Period 2004 – 2005			Period 2005 - 2006		
	Nitrate (mg kg^{-1})		Yield (kg ha^{-1})	Nitrate (mg kg^{-1})		Yield (kg ha^{-1})
	6 Nov.	4 Apr.		11 Nov.	3 Apr.	
CC	125.4±17.1	45.3±3.2	2435±260	88.0±10.0	28.1±5.1	1768±160
CF	52.3±6.5	40.0±2.8	Fallow	120.6±11.3	22.3±3.0	3518±412
CV	62.2±7.3	27.5±1.6	Vetch	40.4±3.5	27.2±4.8	1576±130
CO	50.1±6.2	20.0±0.4	2219±102	26.0±2.3	20.0±3.1	124±38

CC = Conventional barley management; CF = Organic management of barley in rotation with a clean fallow period; CV = Organic management of barley in rotation with vetch; CO = Organic management of barley as a continuous crop.

In November 2005, high soil nitrate levels were again detected in the CC plot – once again because of the recent application of fertilizer. A stronger accumulation of nitrates was recorded, however, after the period of clean fallow in the CF plot, as reported to occur recently under similar conditions (El Mejahed, 1993; Warren et al., 1997). Nitrates also accumulated after the vetch crop in the CV plot, although to a lesser degree than in the CF plot, but more so than in the CO plot. The lower soil nitrate content in the CC treatment compared to the CF treatment might be a consequence of the intense rain that fell during November, and the greater likelihood that the nitrate in the CC conditions should leach out compared to that derived from organic sources mineralised in the soil of the CF plot after the fallow period.

In April 2006, soil nitrate levels were similarly low in all plots due to their strong consumption by the barley; given the low rainfall little could have leached out. From November 2005 to April 2006, the reduction in soil nitrates due to (presumable) plant uptake (taking into account the late fertilizer applications in the CC treatment) were 81.7, 73.3, 32.5 and 23.1% for the CF, CC, CV and CO respectively.

Strong variations in soil nitrate concentrations due to rainfall and plant uptake have also been reported by other authors (Westerman et al., 1994). However, these variations were also due to the type of crop management practised. In both periods, barley grain yields were associated with the pre-sowing soil nitrate content, as reported by El Mejahed (1993) for unfertilised plots. In June 2006, the yield was strongly related to the November 2005 soil nitrate content ($R^2 = 0.84$). The yields obtained in the different treatments followed the order CF > CC > CV > CO; this differs to that reported by López Bellido et al. (2000) who reported higher barely yields after a vetch crop than after a fallow period. A strong relationship was also found between yield and the apparent crop nitrate uptake ($R^2 = 0.97$).

References:

- **Bremner, J.M. (1965).** Inorganic forms of nitrogen. In: *Methods of Soil Analysis. Part 2.* (eds. C.A. Black, D.D. Evans, J.L. White, L.E. Esminger. F.E. Clark), pp 1179-1237. Agronomy 9, American Society of Agronomy, Madison, WI.
- **El Mejahed, K. (1993).** Effect of nitrogen on yield, nitrogen uptake and water use efficiency of wheat in rotation systems under semiarid conditions of Morocco. *Dissertation for the University of Nebraska*, Lincoln 143 pp. (AAT9415960).
- **Kolberg, R.J., Kitchen, N.R., Westfall, D.G. & Peterson, G.A. (1996).** Cropping intensity and nitrogen management impact of dryland no-till rotations in the semi-arid Western Great Plains. *Journal Production Agriculture* 9, 517- 522.
- **López Bellido, L., López Bellido, R.J., Castillo, J.E. & López Bellido, F. (2000).** Effects of tillage, crop rotation and nitrogen fertilization on wheat Ander rainfed Mediterranean conditions. *Agronomy Journal* 92, 1054- 1063.
- **Page, M.B.& Talibudeen, O. (1977).** Nitrate concentrations under winter wheat and in fallow soil during summer at Rothamsted. *Plant and Soil*, 47, 527- 540.
- **Smika, D.E., Black, A.L. & Greb, B.W**. (1969). Soil nitrate, soil water and grain yields in a wheat- fallow rotation in the Great Plains as influenced by straw mulch *Agronomy Journal,* 61, 785- 787.
- **Warren, G.P., Atwal, S.S. & Irungu, J.W. (1997)**. Soil nitrate variations under grass, sorghum and bare fallow in semi-arid Kenya. *Experimental Agriculture,* 33, 321- 333.
- **Westerman, R.I., Boman, R.K., Raun, W.R. & Johnson, G.U.** (1994). Ammonium and nitrate nitrogen in soil profiles of long-term winter wheat fertilization experiments. *Agronomy Journal*, 86, 94- 99.

1956
National Research Centre
(NRC)

1976
Project Micronutrients and
Plant Nutrition Problems

CIEC
International Scientific
Centre of Fertilizers

Proceedings of
the 17th International Symposium of CIEC

PLANT NUTRIENT MANAGEMENT UNDER STRESS CONDITIONS

National Research Centre (NRC)
24-27 Nov. 2008, Cairo - Egypt

2008

© National Research Centre (NRC), 2008-11-16
Project Micronutrients and plant Nutrition Problems , Cairo – Dokki, Egypt.
El-Behooth Str., Dokki, Cairo, Egypt
Tel. : 00 202 33365223 – 33361225 – 33365199
Fax : 00 202 37610850
E-mail : nrc-mic@link.net

Layout :

Prof. Dr. F.E. Abdalla and Dr. A.A. Abdel-Maguid
Fertilization Technology Dept., NRC.

Egyptian National Library Legal Deposit No. 22018 / 2008
ISBN : 977 - 5041 - 60 - 0

Printed in Egypt by :

El-Zaiem Press, Giza - Egypt

INSTITUTO DE CIENCIAS AGRARIAS
CSIC
MADRID