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NITRATE CONCENTRATION AND MICROBIAL ACTIVITIES IN MAIZE CULTIVATED PLOTS UNDER DIFFERENT WEED CONTROL MANAGEMENT

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Abstract - The effects of two weeding methods (1-chemical treatments on the open ground; 2-chemical treatment on rows integrated with hoeings) on respiratory activity, microbial biomass C, metabolic quotient (qCO_2), organic C content, mineralization index, nitrate concentration and potential nitrification activity (PNA) have been evaluated in plot trials on a sandy loam (typic udifluvent, fine lamy, mixed calcarous, mesic) under temperate climate. The data indicated that different weeding systems affected the microbial biomass, qCO_2, soil nitrate content and PNA. The weeding treatment on rows integrated with hoeings was more environmentally acceptable because it allowed a lower quantity of herbicide per surface unit and a lower fertilization input.

Key words: Weeding practices, metabolic quotient, PNA, nitrate content.

INTRODUCTION

Agricultural pesticides have an important role in modern agriculture because they allow crops to produce higher yields, but their effects on the environment should also be considered. The continued use of herbicides has an impact on agroecosystems whose effects are a function of the different compounds used, the dose, the methods of application, the soil type, the temperature and moisture regimes, and soil management practices. Herbicide practices in weed control of maize is only chemical or integrated with mechanical treatments; it is necessary to control the integration of chemical and non-chemical methods to achieve effective weed management. The soil, therefore, is cultivated lightly or rotavated on one or more occasions to contain weeds. Unlike strictly chemical treatments, those integrated with mechanical ones homogenize and destroy part of the structure of the topsoil and macropore continuity, preferential flow pathways such as earthworm burrows, root channels, fissures and cracks (1). This causes a higher availability of nutrients and better conditions for microbial metabolic activities in the superficial profile of the soil (2) and influence solute leaching.

The aim of this research was to evaluate the effects, during maize cultivation, of two different weed control practices (1- chemical treatments on the open ground ; 2- chemical treatment on rows integrated with light ploughs) on certain biological and biochemical processes such as

microbial biomass, soil respiration, organic carbon and potential ammonia oxidizing activity. The mineralization index and the qCO_2 were calculated from the data.

The nitrate concentration in the superficial layer of soil was also evaluated in order to understand wether other factors determined nitrogen fluxes and dynamics, in addition to the most important ones such as weather conditions, temperature and precipitation (3, 4).

MATERIALS AND METHODS.

Soil and treatments - The study was conducted at Fagna Agricultural Experimental Center (Scarperia-Firenze) of the Research Institute for Soil Study and Conservation (Firenze-Italy) on a loam soil typic Udifluvent under temperate climate, whose composition is shown in table 1, and which has been cultivated continously with maize since 1970.

A randomized complete plot design was adopted. Since 1989 each block has been divided into eight plots of 500 m^2 with two weeding treatments:

1. in pre-emergence (23.04.96) on rows with 1.5 kg ha^{-1} PRIMAGRAM TZ (Metolachlor 30% + Terbuthylazine 15%) and two mechanical hoeings (27.05.96 and 7.06.96);
2. in pre-emergence (23.04.96) with 5 kg ha^{-1} PRIMAGRAM TZ and in post-emergence (7.06.96) with 20 g ha^{-1} TELL (Primsulfuron-methyl 75%, used since 1994) on the whole surface.

The nitrogen fertilization with urea was done with 248 kg of N ha^{-1} at seed-time (23.04.96), plus 52 kg ha^{-1} di N at the surface (7.06.96).

The soil samples were collected randomly from the whole plot surface at 0-20 cm of depth for the determination of microbial activities and at 0-20, 20-40, 40-60 cm for the nitrate evaluation. The soil was sieved at 2 mm and kept at 5°C until use. The results obtained refer to the eighth year of weeding treatment.

Tab. 1. Physical and chemical characteristics of the soil.

Soil skeleton	5 %	Organic matter	1.8 %
Sand mm 2 ÷ 0.05	45 %	total K_2O	1.5 %
Silt mm 00.5 ÷ 0.002	38 %	exchangeable K_2O	100 ppm
Clay < mm 0.002	17 %	total P_2O_5	1.3 %
pH	7.8	ass. P_2O_5	65 ppm
Total $CaCO_3$	6 %	total N	0.12 %

Respirometry, biomass and qCO_2 determinations - The respiratory activity was determined after the harvest, according to (5) and modified as follows: the soil samples were divided into 3 subsamples of 100 g, adjusted to 50% of water holding capacity, incubated at 25°C in 1l flasks, containing soda lime. The soda lime was substituted twice in 10 days. The evolved CO_2, as CO_2-C, was measured by gravimetric method and expressed as mg CO_2 Kg^{-1} 24 h^{-1}.

Microbial biomass C was estimated using the following equation: biomass C = $Fc \cdot kc$ (6) where Fc is CO_2-C (evolved from fumigated soil during the 0-10 incubation period) minus CO_2-C (evolved from non-fumigated soil during the same incubation period) and kc is 0.45 (7). The biomass was expressed in mg C Kg^{-1} of dry soil.

For calculation of the qCO_2, the ratio between CO_2-C and biomass-C was considered according to (8).

Organic C - The C_{org} content was evaluated according to the method described by (9).

Mineralization index - The mineralization index was calculated from the ratio between respiratory CO_2 and total organic carbon content.

Potential Nitrifying Activity - The PNA was measured according to (10) and (11) at regular 2-h intervals during an incubation period of 6 h in 2 mM phosphate buffer (pH 7.5) supplemented with 2 mM $(NH_4)_2SO_4$. After centrifugation, the supernatants were mixed with an equal volume of 2 M KCl solution to stop ammonia oxidation. The nitrite and nitrate concentrations were determined using a Technicon Autoanalyzer II System.

Soil nitrate content - Soil samples were collected and kept frozen until analysis. Nitrates were extracted by shaking 20 g of soil in 100 ml of 2M KCl solution for 1 h (12). Soil solution extracts were analysed for NO_3-N by the cadmium-reduction method using a Technicon Autoanalyzer II System. All results were expressed on dry soil basis.

Statistical analysis - The results were statistically tested by one way completely randomized analysis of variance (ANOVA) and Duncan's multiple range test according to the Costat CoHort Software, Berkeley, CA 94701.

RESULTS AND DISCUSSION

Respiratory activity, microbial biomass and qCO_2 - The respiratory activity values, even if they varied during the maize cultivation cycle, did not show significative differences between the two weeding practices (Fig. 1A). The biomass C varied during the crop vegetative cycle; and, after the first treatment, in particular, it was lower in the plots treated with herbicides in open ground

than in the "on row" plots (Fig. 1B). As a consequence, after the first treatment, the metabolic quotient in the open ground plots increased, indicating a more disturbed biomass under this condition. After the post-emergence treatment, the qCO_2 values were not different from those obtained before the first application in the same plots. Moreover, these last data were similar for both weeding practices, indicating that the sulfunilurea did not affect the respiratory activity of the microbial biomass (Fig. 1C). After the first application in the open ground plots, the increase of qCO_2, which is a good bioindicator of disturbance, could be due to the higher amount of herbicide per surface unit.

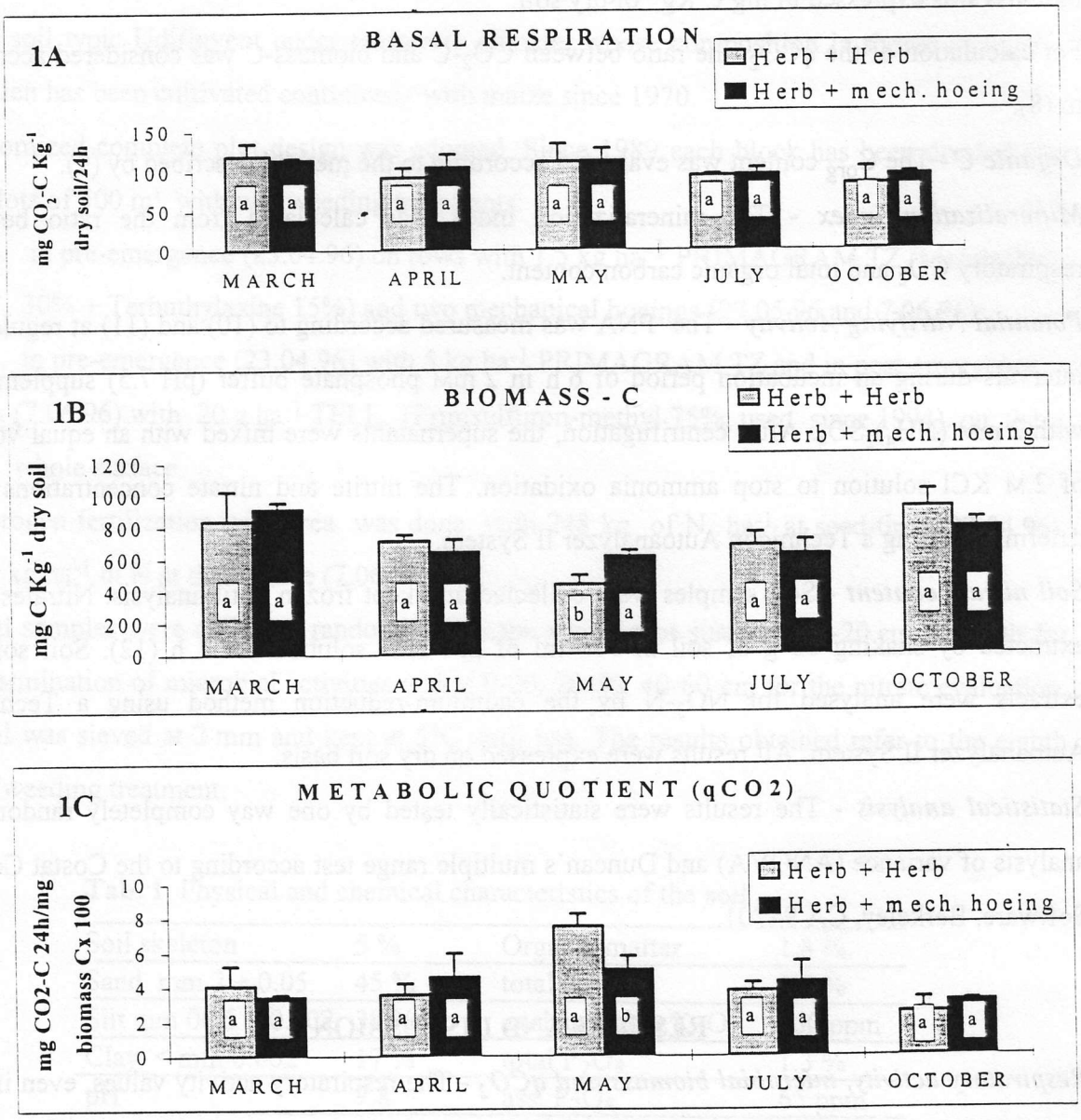

Fig.1. Variations of the basal respiration (**A**), microbial biomass (**B**) and microbial metabolic quotient (**C**) under different weeding practices and Duncan's multiple range test.

Organic C, mineralization index - The organic content values and the mineralization index in the 0-20 cm soil layer were not significantly different between the two weed control treatments (Fig. 2A and B). One reason could be that changes in the organic carbon content of soil are generally slower than those induced in the microbial biomass, which is why this latter parameter may be used as an early indicator of organic matter content (13).

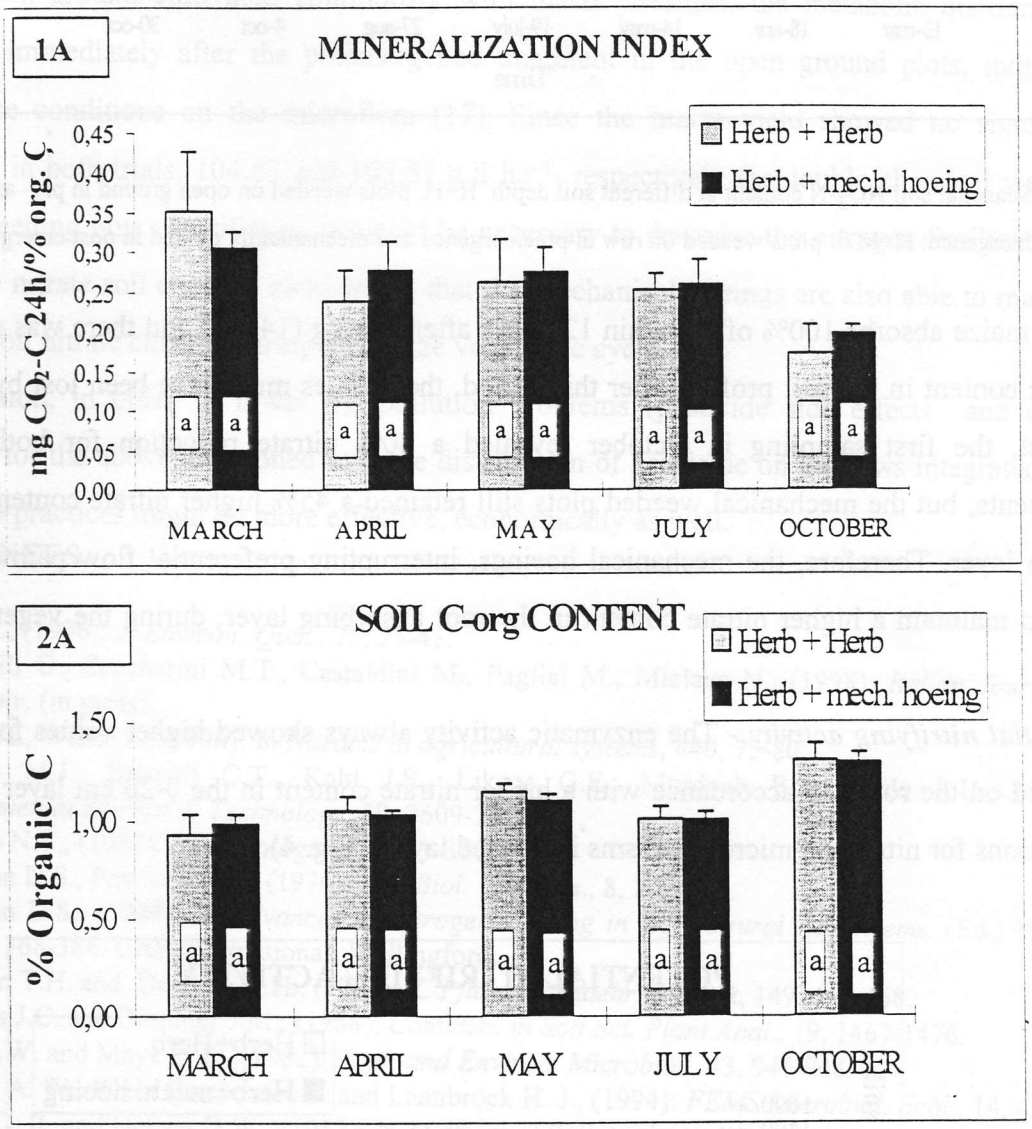

Fig. 2. Mineralization of organic C (**A**) and organic carbon content (**B**) in the soil as affected by different weeding practices and Duncan's multiple range test.

Nitrate content - The nitrate content as $N\text{-}NO_3$, after the main fertilization, increased in the considered profiles for both weedings. The plots treated with mechanical weeding in post emergence always showed a higher nitrate content both in the 0-20 cm profile and in the deeper ones, 20-40 and 40-60 cm, except for the sampling of July for the 40-60 cm depth (Fig. 3).

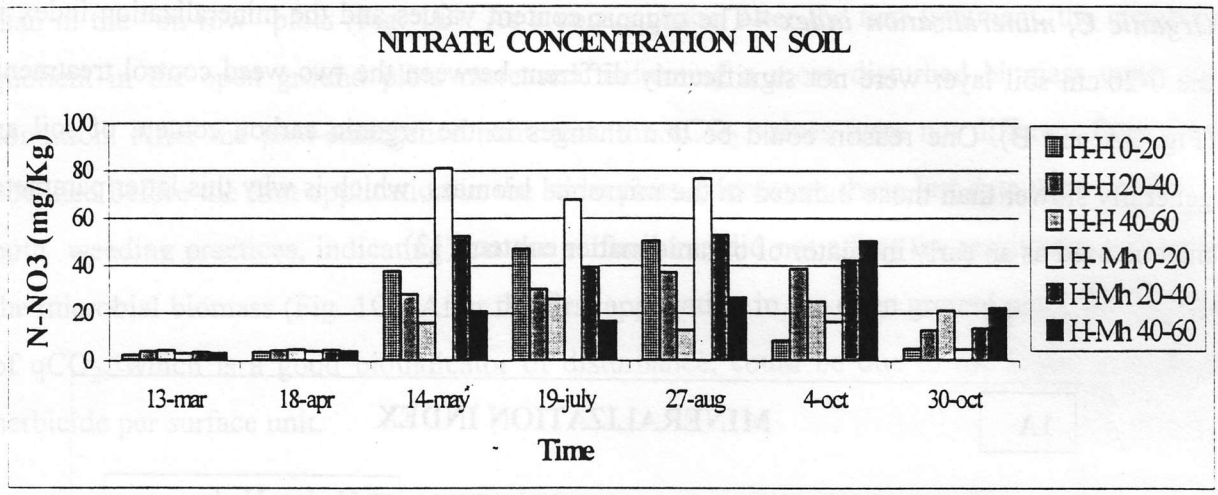

Fig. 3. Seasonal soil NO_3-N content at different soil depth. H+H: plots weeded on open ground in pre- and post-emergence; H+M.h: plots weeded on row in preemergence and mechanically treated in post emergence.

Since maize absorbs 100% of N within 120 days after sowing (14, 15) and there was still a high nitrate content in the soil profiles after this period, the nitrates must have been lost by leaching. In fact, the first sampling in October revealed a 80% nitrate reduction for both weeding treatments, but the mechanical weeded plots still retained a 45% higher nitrate content in the 0-20 cm layer. Therefore, the mechanical hoeings, interrupting preferential flow pathways, were able to maintain a higher nitrate content in the root absorbing layer, during the vegetative corn cycle.

Potential nitrifying activity - The enzymatic activity always showed higher values for the plots weeded on the rows, in accordance with a higher nitrate content in the 0-20 cm layer and better conditions for nitrifying microorganisms in aerated layers (Fig. 4).

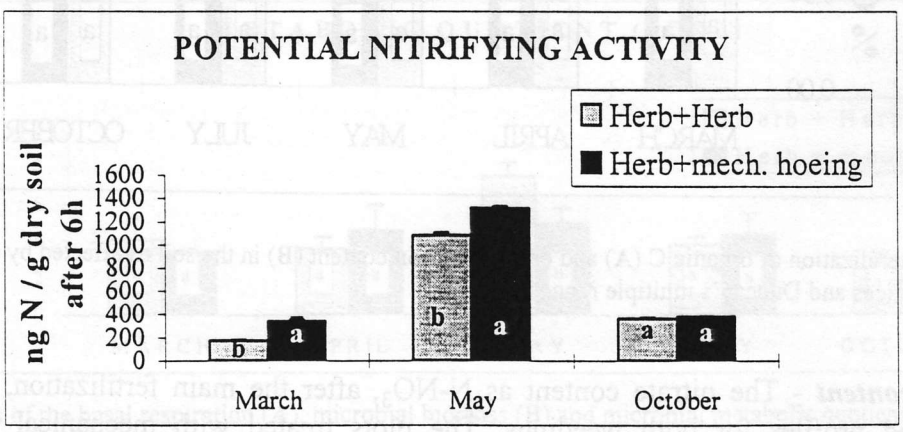

Fig. 4. Potential nitrifying activity measured as NO^{2-}+NO^{3-} in soil suspensions from the studied plots.

CONCLUSION

Potential nitrifying activity, evaluated before, during and after the vegetative corn cycle, was always higher in the plots weeded on the rows and with mechanical hoeings; this could be due to the different quantity of the herbicide used in the considered weeding practices, and even if Bremner (16) found that the two active substances in preemergence did not have effects on nitrification separately, it is not possible to exclude a certain inhibitory action when used together and in open ground cultivated continously with maize. Besides, the metabolic quotient also increased immediately after the preemergence treatment in the open ground plots, indicating disturbance conditions on the microflora (17). Since the maize yield showed no significant difference in both trials, 104.63 and 103.67 q.li ha^{-1}, respectively for double chemical weeding and for weeding plus two tillages, it would be necessary to decrease the nitrogen fertilization to reduce the nitrate soil content, considering that the mechanical hoeings are also able to maintain a greater soil nitrate content during the maize vegetative cycle.

In conclusion, in order to lower the pollution problems (pesticide side effects and nitrate leaching), for the above mentioned soil, the distribution of herbicide on the rows integrated with intertillage practices might be more effective, economically as well.

REFERENCES

1. Flury M., (1996): *J. Environ. Qual.*, 25, 25-45.
2. Piovanelli C., Ceccherini M.T., Castaldini M., Pagliai M., Miclaus N., (1998): *Italian Journal of Agronomy*, (in press).
3. Dechnik I., Wiater J., (1996): In *Nitrates in agricultural systems*, 440, 75-80.
4. Mitchell M.J., Driscoll C.T., Kahl J.S., Likens G.E., Murdoch P.S., Pardo L.H., (1996): *Environmental Science & Technology*, 30, 2609-2612.
5. Edwards N.T., (1982): *Pedobiologia*, 23, 321-380.
6. Jenkinson D.S., Powlson D.S., (1976): *Soil Biol. Biochem.*, 8, 209-213.
7. Jenkinson D.S., (1988): In *Advances in Nitrogen Cycling in Agricultural Ecosystems*. (Ed.) Wilson J.R., pp. 368-386. CAB International, Wallingford.
8. Anderson T.H. and Domsch K.H., (1986): *Z. Pflanzenernaehr. Bodenk*, 149, 457-468.
9. Yeomans J.C. and Bremner J.M., (1988): *Commun. in Soil Sci. Plant Anal.*, 19, 1467-1476.
10. Belser L.W. and Mays E. L., (1982): *Appl. and Environ. Microbiol.*, 43, 945-948.
11. Stienstra A. W., Klein Gunnewiek P. and Laanbroek H. J., (1994): *FEMS Microbiol. Ecól.*, 14, 45-52.
12. Keeney D. R. and Nelson D.W., (1982): In *Methods of Soil Analysis, Part 2*, ed. A. Page, pp. 643-689. Madison, WI - USA.
13. Powlson D.S., Brookes P.C. and Christensen B.T., (1987): *Soil Biol. Biochem.*, 19, 159-164.
14. Aldrich S.R. and Leng E.R., (1965): In *Modern Corn Production*. F & W Publishing Corp., p. 97. Farm Quarterly, Cincinnati, Ohio - USA.
15. Baldoni R and Giordani L., (1982): In *Coltivazioni Erbacee*. Patron editor, Bologna, p. 140.
16. Bremner J.M., (1995): *Fertilize Research*, 42, 321-329.
17. Wardle D.A. and Ghani A., (1995): *Soil Biol. Biochem.*, 12, 1601-1610.

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