# PIG SLURRY APPLICATION ON ALFALFA: WHAT CAN WE GAIN IN TERMS OF CARBON CYCLE?

***E. Ceotto, P. Spallacci, R. Marchetti***
*Istituto Sperimentale Agronomico, Sezione di Modena, Viale Caduti in Guerra 134, 41100 Modena, Italy. ceotto@pianeta.it (Ceotto)*

## ABSTRACT

An alfalfa stand, established in 1993, was treated for two subsequent years (1994 and 1995) with four rates of pig slurry, named as Control (unfertilized), PS 300, PS 450, and PS 600 referred to kg N $ha^{-1}$ $year^{-1}$. During the last two years of the crop stand (1996 and 1997) the residual effect of the biennial treatments was investigated. Our finding indicates that alfalfa, displaced from its traditional role of N fixing crop, could provide a valuable option for manure recycling whilst improving land productivity and soil C sequestration.
***Keywords:*** *Alfalfa, pig slurry, C sequestration, N removal.*

## INTRODUCTION

Alfalfa (*Medicago sativa L.*) normally obtains most of the nitrogen (N) needed for its growth by establishing association with N-fixing bacteria. The reduction of atmospheric $N_2$ to ammonia, however, is energy intensive and requires substantial carbon (C) costs for the reaction itself and for growth and maintenance of nodulated roots (Ryle et al.,1979). Thus, when nitrates are abundantly available in the soil, $N_2$ fixation is inhibited and the crop takes advantage of available N at lower C costs. Owing to such flexibility in using N different sources, alfalfa can provide a valuable nitrate-scavenging service in situations prone to ground water pollution (Loomis and Connor, 1992). Consequently, alfalfa is well suited to receive manure applications and fits well into crop rotations in areas with intensive livestock activities (Daliparthy et al., 1994).

So far, most of the studies regarding manure application to alfalfa were focussed on soil nitrate control. Recently, the legume crops have received a renewed interest as an alternative N route with respect to industrial fertilizers (Drinkwater et al., 1998; Crews and Peoples, 2004). This interest is due to the growing concern about the environmental consequences of a massive use of fossil energy and the related increase of $CO_2$ in the atmosphere.

The aim of this paper was to explore the possibilities of enhancing C sequestration of agricultural land by manure application on alfalfa. A case study is reported for direct and residual response to pig slurry application throughout four years of an alfalfa stand.

## MATERIALS AND METHODS

A field experiment was conducted from 1994 to 1997 at the Station of Istituto Sperimentale Agronomico, located in S.Prospero (Modena), Low Po Valley, Northern Italy (Lat. 44°47’ N, Long. 11°02’ E, 23 m a.s.l.). The soil of the site is classified as Vertic Ustochrept. An alfalfa stand, established in 1993, was treated for two subsequent years (1994 and 1995) with four rates of pig slurry, named as Control (unfertilized), PS 300, PS 450, and PS 600, referred to kg N $ha^{-1}$ $year^{-1}$, in a randomized block experiment with two replications. The size of individual plots was 258 $m^2$. During the last two years of the crop stand (1996 and 1997) the residual effect of the biennial treatments were investigated. All the annual rates of application were fractionated in four applications providing 20-30-25-25% of the total amounts. The first two fractions were applied at the beginning and at the end of winter, whilst the remaining two fractions were applied after first and second forage cuts. Pig slurry was distributed on soil surface. Liquid pig manure was collected from open-air lagoon and stored on a closed tank, where it was kept in agitation by a mixing pump in order to obtain uniformity in composition, and sampled to determine its nutrients content. The volumes of manure to be applied were determined on the basis of total N concentration. Standard analytical methods for determination of N content of manure and plant dry matter were used according to Cottenie (1979). Shoot biomass was harvested at half flowering. Five cuts were performed in 1994 and four cuts in each of the remaining years. A C content of 45% for dry matter was assumed according to Paustian et al. (1990). The cumulative above-ground net primary productivity (ANPP), defined as the C uptake by crop photosynthesis minus the C losses via crop respiration (Prentice et al., 2000) was considered as a response variable.

## RESULTS AND DISCUSSION

The patterns of ANPP for individual treatments throughout four years of alfalfa stand are shown in figure 1. ANPP declined, as expected, from the second to the fifth year of crop stand. This is a common behaviour due to crop ageing, repeated cuts and climatic stresses. However, regardless of crop age and year-to-year variability, pig slurry fertilization always increased annual ANPP of 10-30%. Overall, the treatments PS 300, PS 450, and PS 600 increased ANPP with respect to Control of 248 (14 %), 484 (28 %) and 305 (17 %) g C $m^{-2}$, respectively. It is important to notice that all rates of pig slurry application had a substantial residual effect.

The patterns of N removal (g N $m^{-2}$) with ANPP are reported in table 1. Since the N concentration in biomass was fairly stable regardless to fertilization, then N removal was essentially driven by ANPP. Overall, the treatments PS 300, PS 450, and PS 600 increased N removal with respect to Control of 15.6 (14 %), 29.2 (26 %) and 16.5 (15 %) g C $m^{-2}$, respectively.

Several studies indicated that the inclusion of alfalfa into cropping sequences lead to an increase of organic C in soil profile. Robertson et al. (2000) reported that alfalfa added 32 to 44 g C $m^{-2}$ year to the soil C pool. Anger (1992) reported that soil C content under alfalfa increased of 26-30 g $kg^{-1}$ $year^{-1}$, following a sigmoidal trend during five years of crop stand. This author pointed out that alfalfa increases soil organic C due to abundance of below-ground biomass and also to the decrease of soil disturbance from tillage operations. In addition, the deep rooting system of alfalfa allows the raise of organic C at depths of soil profile far outside the capability of the annual crops. The evaluation of the effects of treatments on soil organic C is still on going for the present experiment. Nevertheless, it can be hypothesized that observed increase in ANPP lead to a similar increase in below-ground net primary productivity, and consequently to a substantial raise in soil organic C.

Olness et al. (2002) pointed out that N represents a critical aspect of soil C sequestration. Since N is about 9 % of soil organic matter (SOM), a source of N is needed in order to allow the storage of C in soil profile. The authors calculated that an increase of 0.1 % in soil organic C for a layer of 0.15 m, assuming bulk density of 1.2 and nitrogen efficiency of 50 %, requires 328 kg N $ha^{-1}$. Consequently, when the N embodied in soil organic matter is provided by industrial fertilizers an environmental cost in terms of fossil energy used (and $CO_2$ released) should be taken into account. Conversely, in case of manured alfalfa the energetic cost is zero because the N contributed by the crop residuals is either from N fixation or from recycled animal wastes.

In literature there are contrasting views about the potential role of legumes within cropping systems. Some authors (Crews and Peoples, 2004; Drinkwater et al., 1998, Tillman, 1998) support the view that sustainable land use would be greatly improved by using legume crops as a main route of N in substitution of industrial fertilizers. Such strategy would reduce the reliance of agriculture on fossil energy. In contrast, Sinclair and Cassman (1999) contend that the increasing food demand from human population already exceeds the low carrying capacity of legume-dependent cropping systems. We share the view that any effort should be made to achieve optimal levels of biomass production per unit area. This would permit to maximize the land available for unmanaged ecosystems. In this context, our findings indicate how alfalfa, displaced from its traditional role of N fixing crop, could provide a valuable option for increasing land productivity per unit area, whilst providing a viable option for both nutrient recycling and soil C sequestration. In fact, pig slurry fertilization can minimize the area required for crop production, because 25 % more area is required to achieve the same ANPP with an unfertilized alfalfa stand.

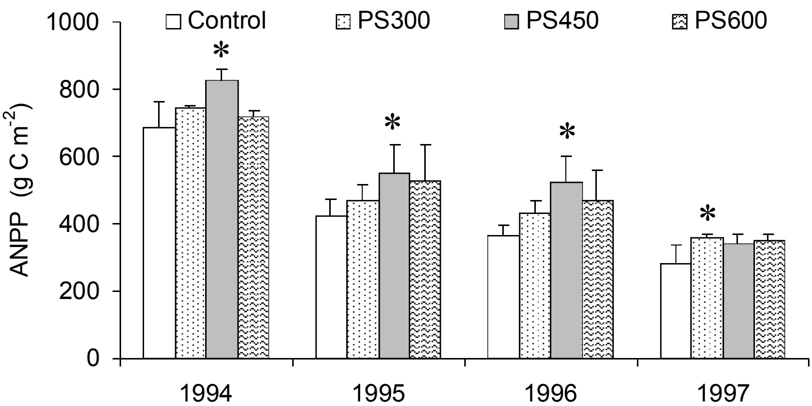


***Figure 1**. Patterns of aboveground net primary productivity (ANPP) for individual treatments throughout four years of crop stand. Values are means ± s.e.m. Asterisks indicate significant differences with respect to Control within individual years, ANOVA, P = 0.05.*

***Table 1**. Patterns of N removal (g N m$^{-2}$) with ANPP for individual treatments throughout four years of crop stand. Values are means ± s.e.m. Means with the same letters are not significantly different within individual years, ANOVA, P = 0.05. Delta values (Δ N) denote the increments achieved by individual fertilization treatments with respect to control.*

| | Control | PS 300 | PS 450 | PS 600 |
|---|---|---|---|---|
| 1994 | 43.2 ± 3.98 **b** | 47.0 ± 0.05 **ab** | 52.1 ± 3.14 **a** | 45.1 ± 2.07 **ab** |
| 1995 | 28.9 ± 3.04 **a** | 32.0 ± 1.83 **a** | 36.5 ± 5.30 **a** | 34.3 ± 7.85 **a** |
| 1996 | 21.6 ± 2.07 **b** | 25.8 ± 1.82 **ab** | 30.2 ± 3.55 **a** | 26.6 ± 5.56 **ab** |
| 1997 | 18.9 ± 3.89 **a** | 23.2 ± 0.71 **a** | 22.8 ± 2.40 **a** | 23.1 ± 0.86 **a** |
| total | 112.5 | 128.1 | 141.7 | 129.1 |
| **Δ N*** | | **15.6** | **29.2** | **16.5** |
| | | + 14 % | + 26 % | + 15 % |

## CONCLUSIONS

Our results show that pig slurry fertilization on alfalfa has an important role in enhancing the efficiency by which the (renewable) solar energy is used by the crop to sequester atmospheric C and to remove N from the soil. Then, alfalfa could provide a valuable option for manure recycling whilst improving land productivity and soil C sequestration. The environmentalist pressure to utilize $N_2$ fixing crops as source of N for cropping systems should be balanced against the even more important goal to sustain optimal productivity per unit area. Therefore, in areas facing problems of manure surplus, the flexibility of alfalfa in using alternative N-sources can be better exploited in recycling animal wastes rather than to substitute industrial fertilizers.

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