FAO European Cooperative
Research Network

Recycling of Agricultural, Municipal and Industrial Residues in Agriculture

Network Coordinator: José Martinez, Cemagref, Rennes (France)

RAMIRAN 2002

Proceedings of the 10th International Conference of the RAMIRAN Network

General Theme: Hygiene Safety

Štrbské Pleso, High Tatras, Slovak Republic
May 14 - 18, 2002

Edited by Ján Venglovský and Gertruda Gréserová

ISBN 80-88985-68-4

University of Veterinary Medicine
Research Institute of Veterinary Medicine
Hlinkova 1/A
040 01 Košice
Slovak Republic

EFFECTS OF PIG MANURE APPLICATION ON THE EFFICIENCY OF RADIATION UTILIZATION IN PURE ALFALFA STAND

E. CEOTTO, P. SPALLACCI

Istituto Sperimentale Agronomico - Sezione di Modena, Viale Caduti in Guerra, 134 - 41100 Modena, ITALY; e-mail: ceotto@pianeta.it

ABSTRACT

This study was conducted to assess whether pig slurry application on alfalfa (Medicago sativa L.) is a convenient land use management. There is a linear relation between shoot biomass production and the amount of total incident solar radiation throughout the growing season. We found that the regression slope, indicating the amount of biomass produced per unit of incident radiation, is substantially increased by an adequate supply of nitrogen as pig slurry. We propose that this situation can be defined as "manure subsidized production condition". Thus, we concluded that alfalfa is a viable alternative crop, with respect to maize, for efficient manure utilization.

INTRODUCTION

In areas with intensive livestock activities, manure is predominantly applied to maize. The identification of alternative crops for viable slurry distribution, may lead to take advantage of crop rotations without reducing the area annually available for manure spreading. In addition, the increasing concern for food security determines a renewed interest in leguminous crops as "safe source" of proteins for livestock feeding. Despite to its independence from N fertilization, alfalfa (Medicago sativa L.) may remove substantial amount of nitrogen (N) from the soil due to the inhibition effect on symbiotic N fixation which occurs when nitrates are abundantly available in the substrate (Peterson and Russelle, 1991).

Two physiological traits play a key role in defining the biophysical potential for a crop: i) the capability of intercepting incident solar radiation throughout the season; ii) the efficiency in converting that energy into new biomass (Monteith, 1977). Due to its perennial nature, alfalfa extends its canopy cover throughout the useful growing season, thus assuring an efficient radiation capturing. The ratio between biomass produced (gm^{-2}) and radiation intercepted ($MJ\ m^{-2}$) defines the crop radiation-use efficiency (RUE). In comparing RUE of several crop species, Gosse et. al. (1986) found higher values for C_4 species with respect to C_3 species, and within C_3 species, higher RUE values for non leguminous species and lower RUE values for leguminous species. This is due to the high growth respiration losses related to the composition of structural biomass (Ryle et. al. 1979), and to the additional carbon cost necessary to sustain symbiotic organisms (Asseng and Hsiao, 2002). On the basis of a recent RUE review of Sinclair and Muchow (1999) there have been no report on alfalfa crop using the usual approach in which radiation interception is accounted for. Indeed, some difficulties arise in evaluating RUE for alfalfa due to the perennial nature of the crop, and consequently to its fluctuating sink-source relationships between shoots and roots. Nevertheless, a simplified evaluation of the photosynthetic efficiency of an alfalfa was performed by Sinclair and Randall (1993) who plotted the cumulative harvested shoot biomass against the cumulative incident solar radiation (Rg), finding strong linear relationships.

The objective of this study was to assess whether manure application could improve the efficiency of solar radiation use in alfalfa, thus providing an agronomic advantage for slurry distribution on this crop.

MATERIALS AND METHODS

A field experiment investigating the effects of pig manure application on growth of alfalfa was conducted in Modena, Northern Italy (Lat. 44° 38' N, Long. 10° 50' E), during the years 1994 and 1995. The soil of the site is a Vertic Ustochrept, with a plant available water holding capacity of about 150 mm per meter of depth. An alfalfa crop, established in 1993, was treated for two subsequent years with four rates of pig slurry, named as PS 0 (control), PS 150, PS 300, PS 450, referred to kg N ha^{-1} $year^{-1}$, in a randomized block experiment with two replications. For sake of brevity, other treatments included in the experiments are not reported here. The crop was fully irrigated, and in order to avoid competition, grass species were controlled chemically at the end of the winter. Incident global radiation (Rg) was measured continuously during growing seasons 1994 and 1995, using a Starpyranometer (0.3 - 3.0 µm, Ph. Shenk, Wien, Austria), in the meteorological area beside to the experiment. Data were recorded electronically. Daily values of Rg were accumulated from 1 April (data at which approximately alfalfa starts growing) until the last forage harvesting. Shoot biomass were harvested at half flowering and data refers to the whole plots, with individual dimension of 258 m^2.

RESULTS AND DISCUSSIONS

The linear relationships between accumulated shoot dry matter and cumulative incident radiation in the two subsequent years are shown in figure 1. In 1994 the unfertilized control produced 0.36 g (DM shoot) MJ^{-1} Rg. This value is very close to the ones (0.31-0.35) reported by Sinclair and Randall (1993) for alfalfa in Florida. The treatment PS 450 increased the efficiency to 0.43 g MJ^{-1}. Higher pig slurry supply didn't determine any additional increase in radiation conversion into biomass (data not shown). Sinclair and Horie (1989) indicated theoretical and experimental evidence for a curvilinear saturating response of RUE to N content of the leaves. Then, for a proper interpretation of the results it is important to assess weather the increased conversion efficiency was related with increased nitrogen concentration in shoot biomass. Data reported in figure 2 indicate no response of pig slurry application on N concentration in shoot biomass. Loomis and Connor (1992), highlighted the facultative nature of Rhizobium fixation, which is repressed by the presence of mineral N. Consequently, it is likely that an abundant supply of N increased the conversion efficiency of the crop by reducing the carbon cost necessary to sustain symbiotic organisms.

Figure1. Relationships between cumulative harvested shoot biomass and cumulative incident solar radiation for four rates of pig slurry supply on the years 1994 and 1995. The slope of regression lines is the estimated efficiency of radiation utilization (g MJ^{-1}).

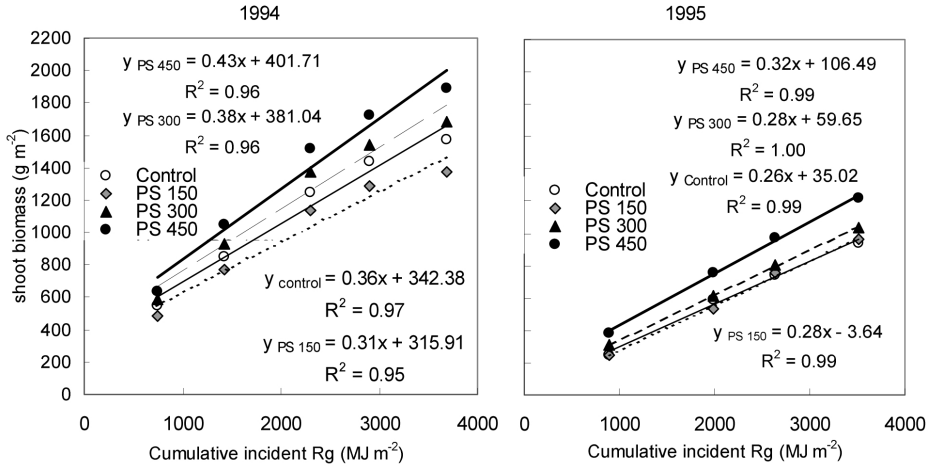
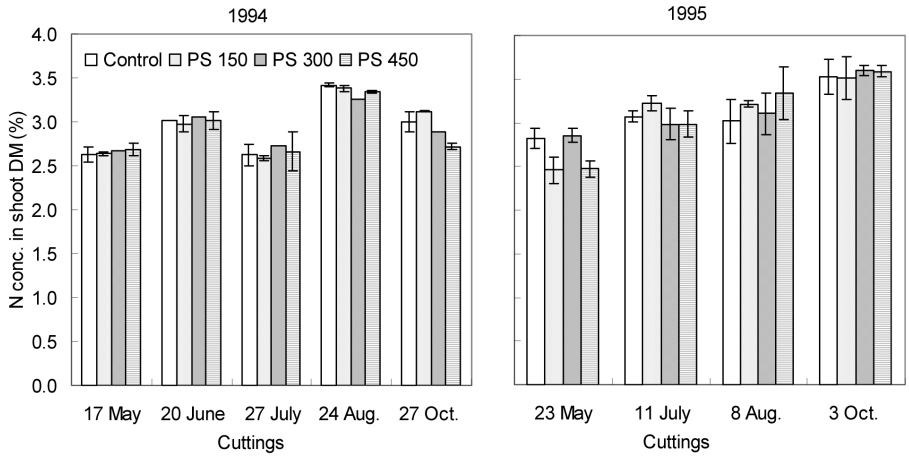


Figure2. Nitrogen concentration in shoot dry matter for the several treatments and forage harvesting throughout 1994 and 1995. Standard errors of the mean are indicated as vertical bars.



In fact, as Asseng and Hsiao (2002) pointed out, N fixing bacteria and vescicular-arbuscular mycorrhizal fungi that may consume more than 20% of the host's photosynthate.

Despite to the positive response of higher pig slurry rates of supply, the treatment PS 150 determined a conversion efficiency of 0.31 g MJ^{-1}, a lower value with respect to the untreated control. Our explanation is that the amount of N supplied with this treatment interfered with symbiotic activities without providing all the nitrogen required to fulfill the crop needs.

In the subsequent year 1995, the linear relationships were characterized by lower values for the intercept and slope. The lower intercepts may be attributed to the lower source-strength of the rooting systems of the alfalfa stand at its third year. The lower values for conversion efficiency was likely due to ageing of alfalfa stand that determined a lower stems density and therefore a reduced Rg interception. However, it is important to point out that, for both years, the difference in efficiency between PS 450 and the untreated control was 0.06-0.07 g MJ^{-1}, corresponding to + 19 % with respect to control in 1994 and + 23 % in 1995. This order of magnitude is consistent with the entity of carbon cost indicated by Asseng and Hsiao (2002).

An increasingly applied framework to evaluate crop production situations is based on the distinction among potential, nutrient limited and water limited production conditions (Rabbinge, 1993). When the crop is growing under abundant availability of water and nutrients, then solar radiation, temperature, and crop characteristics are the growth defining factors determining the length of the growing season, the radiation intercepted and therefore the potential yield. For non-leguminous crops, the potential condition need to be supported by N fertilization. This is due to the fact that soil N mineralization is almost always insufficient to fulfill the requirements of the crops. Conversely, leguminous crops are a particular case of self-independence form N supply, providing that symbiotic N fixation is effective. Thus, for alfalfa a full availability of water and P already define potential production conditions. Nevertheless, as reported above, a higher production can be obtained by manure application that diminished crop dependence of symbiosis and consequently the overall carbon cost for crop production. We propose that this situation can be described as "manure subsidized production condition". The gap between manure subsidized and potential crop production conditions provide a quantification of the agronomic value of pig slurry.

Moreover, if a broader environmental perspective is considered, it is appropriate to highlight here other valuable features of alfalfa. Firstly, Loomis and Connor (1992) reported that an alfalfa crop yielding 20 t ha^{-1} can remove 56 kg P ha^{-1}, whereas a good maize crop removes somewhat less P (30-40 kg ha^{-1}). Secondly, with respect to maize, which traditionally receives pig slurry spreading, the alfalfa crop doesn't require soil tillage operations for 3-4 years. Recent concern of global climate change have emphasized the importance to reduce tillage in order to increase the soil organic matter (Aslam et al. 2000). This allow the soil to act as a carbon sink, and also help to reduce the use of fossil fuel.

CONCLUSIONS

It was evident from this experiment that, regardless to crop age and year to year variability, application of pig slurry corresponding to 450 kg N ha^{-1} y^{-1} improves the efficiency of solar radiation utilization of alfalfa of about 20 % with respect to the untreated control. The yield response of alfalfa was accompanied, within the rate of application considered here, by lack of accumulation of mineral nitrogen in soil profile at the end of growth season (Spallacci et al.,1999). Therefore, alfalfa is a viable alternative crop, with respect to maize, for efficient manure utilization.

ACKNOWLEDGEMENTS

This work was funded by National Research Council (CNR), Programma Reflui, legge 95/95.

The field experiment was financed by the Italian Ministry of Agricultural Policy. Finalized Project "PANDA", Subproject 2.

REFERENCES

Aslam, T., Choudhary, M.A., Saggar, S., 2000. Influence of land-use management on CO_2 emissions from a silt loam soil in new Zealand. Agriculture, Ecosystems and Environment, 77:257-262.

Asseng, S., Hsiao T. C., 2000. Canopy CO_2 assimilation, energy balance, and water use efficiency of an alfalfa crop before and after cutting. Field Crops Res. 67:191-206.

Gosse, G., Varlet-Grancher, C., Bonhomme, R., Chartier, M., Allirand, J.M., Lemarie, G., 1986. Production maximale de matiere seche et rayonemment solaire intercepte par un couvert vegetal. Agronomie 6, 47-56.

Loomis, R.S., Connor, D.J., 1992. Crop ecology: productivity and management in agricultural systems. Cambridge University Press.

Monteith, J.L., 1977. Climate and efficiency of crop production in Britain. Philos. Trans. R. Soc. Lond. Ser. B. 281, 277-329.

Peterson, T.A., Russelle, M.P., 1991. Alfalfa and the nitrogen cycle in Corn Belt. J. Soil Water Conserv., 46:229-235.

Rabbinge, R.,1993. The ecological background of food production. In: Crop protection and sustainable agriculture. Ciba Foundation Symposium 177. 2-29.

Ryle, G.J.A., Powell, C.E., Gordon, A.J., 1979. The respiratory costs of nitrogen fixation in soybean, cowpea, and white clower. I. nitrogen fixation and the respiration of nodulated root. J. Exp. Bot. 30:135-144.

Sinclair, T.R., Horie, T., 1989. Leaf nitrogen, photosynthesis and crop radiation use efficiency: a review. Crop Sci. 29, 90-98.

Sinclair, T.R., Randall, H.C., 1993. Nitrogen and biomass accumulation by alfalfa under high temperatures of late summer. Field Crops Res., 31: 287-294.

Sinclair, T.R., Muchow, R.C., 1999. Radiation use efficiency. Adv. Agron. 65, 125-265.

Spallacci P., Ceotto E., Papini R., Marchetti R., 1999. La somministrazione dei liquami suini al medicaio: produttivita e bilancio dell'azoto in terreno argilloso. Riv. di Agron. 33:23-33.