SEQ-CURE: A LIFE PROJECT ON THE USE OF ORGANIC RESIDUES IN ENERGY CROPS FERTILISATION

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1 INTRODUCTION

Seq-Cure "Integrated systems to enhance sequestration of carbon, producing energy crops by using organic residues" is a three-year (2007-2010) LIFE III project coordinated by CRPA, designed to demonstrate how organic residues can be used successfully in the cultivation of biomass intended for the production of renewable energy, contributing both to the reduction of CO_2 emissions and to the sequestration of significant quantities of C in the soil. Three types of biomass energy chains at farm level have been considered in the project, based on: 1) combustion of biogas from anaerobic digestion of residues and energy crops, 2) combustion of raw vegetable oil obtained from crushing of seeds; 3) combustion or gasification of wood and fibres.

The economic efficiency of the agroenergy chains requires particular attention, specially, key factors for maximum biogas yields are species and variety of energy crops, time of harvesting, mode of conservation and pre-treatment of the biomass prior to the digestion process but also the nutrient composition of the energy crop (Amon et al., 2007)

The objective of this study was to evaluate the use of organic residues such as manure and digestates to fertilise energy crops used in biogas production in order to improve biomass yields and environmental sustainability. The crops chosen for the biogas energy chain were triticale *(× Triticosecale*) and sorghum (*Sorghum bicolor Moench).* The latter included both sweet sorghum and forage sorghum, the varieties with highest dry matter yields and, as such, of greatest interest for this energy chain. Triticale shares some of wheat's more valuable characteristics, like productivity and good protein content as well as several of the properties of rye, such as rusticity, resistance to diseases of the leaf apparatus and to cold temperatures. Moreover, like other winter cereals, it provides soil covering in winter thereby limiting leaching of nitrogen into the ground water. Its high biogas yield makes it particularly interesting for biomass production. Sorghum is also an interesting crop for biomass production for anaerobic digestion due to its capacity to adapt to different environmental conditions. In fact, thanks to its tolerance to drought and its ability to adapt to marginal zones, it can be considered as an alternative crop to maize wherever the availability of water for irrigation purposes becomes a limiting factor.

2 MATERIALS AND METHODS

The use of organic residues such as manure and digestates to fertilise energy crops was monitored during 3 monitoring campaigns (2007-2009) in 4 different demonstrative farms across the Emilia-Romagna Region in northern Italy. This paper discusses the results obtained during 2008 for the biogas chain.

One variety of triticale was sown in all the biogas demonstrative farms, followed by the sowing of two varieties of sorghum (sweet and forage sorghum). Each trial was set up in such a way as to be able to compare two kinds of fertilisers (organic residues and inorganic fertiliser) for each crop, using the same N available rate as that of a test without fertilisation. The N-rate was calculated using the software Sim.Ba-N (Bortolazzo et al., 2009). No irrigation was applied to sorghum trials.

Dry-matter yields were measured at harvest. Total N from vegetal samples was determined to calculate the nitrogen uptake and efficiency.

To follow nitrate dynamics, and thus the risk of nitrate leaching, soil samples were taken from each site at a depth of 0-25 cm at least three times during the cropping season.

3 RESULTS AND DISCUSSION

The characteristics of the soils where trials were held are summarised in table 1.

TABLE 1 **Soil characteristics and texture**

Farm	Province	Soil texture	N (DM %)	O.M (DM %)
PC01	Piacenza	Loam	0.18	2.4
RE01	Reggio Emilia	Clay	0.13	1.9
BO01	Bologna	Loam	0.11	1.5
RA01	Ravenna	Silty – clay	0.19	2.4

3.1 Triticale (× *Triticosecale*) trials

So far as triticale was concerned, the same variety was sown in all locations. Results from the trials show that the dry-matter yield varied from a minimum of 8.6 Mg ha^{-1} up to a maximum of 15.1 t Mg ha^{-1}. The best results were obtained when organic residues (manure or digestates) were applied before sowing. There were no differences between the dry-matter yield obtained using mineral fertilisers or organic fertilisers applied as top dressing when crops were actively growing, the only case where a difference was found was of about 2,5 Mg ha^{-1} of dry matter between the inorganic fertiliser and the organic fertiliser applied as top dressing for PC01. The low yield obtained for the organic fertiliser in RA01 was due to late fertilisation. Heavy rains in March prevented fertilisation from being applied in time for the trial.

Uptake and N-efficiency (table 2) confirm the above results, with maximum yields being obtained when organic material was distributed before sowing and, at the same time, maximum values of N uptake and efficiency being obtained for the same treatment, digestates in particular, showing N-efficiency of about 88%. In fact, for digestates, N-NH_4 content was 65-70% of total N, while N-NH_4 content in cattle slurries was about 40% of the total N content in the slurry. The lower yields obtained with ammonium nitrate and organic fertiliser treatments used as top dressing, determined lower N-efficiency and N uptake. Although for top dressing treatments it was expected a better performance of inorganic fertilizers, no difference was found and this is maybe because slurries applied as well as digestates contains an important amount of water which helps N to be easily available for plants. On the other hand, the period where the top dressing was done, rains were very scarce.

Initial N content in soils, in some of the farms was high due to frequent distributions of organic fertilisers. In these cases, the N uptake was very high also for the test.So far as the effects on soil nitrate content were concerned, there was no accumulation of nitrates due to the any of the treatments at harvest (Table 2).

TABLE 2 **DM Yield, N content in plants and N uptake and efficiency**

Farm	Fertiliser	N rate (kg N ha^{-1})	Yield Mg DM ha^{-1}	N uptake kg N ha^{-1}	N-efficiency %	Soil NO_3^- Index harvest/sowing
PC01	Test	0	10.79	142	-	0.48
	Ammonium nitrate	80	11.75	154	14.4	1.03
	Cattle manure (before sowing)		15.14	188	56.6	0.81
	Cattle manure top dressing		14.42	160	22.0	0.71
RE01	Test	0	11.00	98	-	0.48
	Ammonium nitrate	121	13.21	143	37.4	0.61
	Pig manure (before sowing)		14.64	161	52.2	0.71
	Pig manure top dressing		13.08	144	38.0	0.97
BO01	Test	0	9.67	204	-	0.12
	Ammonium nitrate	90	10.78	240	41.1	0.07
	Digestate (before sowing)		12.70	283	88.4	0.12
	Digestate top dressing		11.11	256	59.1	0.10
RA01	Test	0	10.17	144	-	0.49
	Ammonium nitrate	100	11.38	193	48.8	0.98
	Digestate top dressing		8.56	127	-17.6	0.99

3.2 Sorghum (*Sorghum bicolor Moench*) trials

The trials were divided in two groups: the first involved PC01 and RE01 and the second BO01 and RA01. The difference between groups was that for the first group, sorghum was sown as the main crop while in the second group, sorghum was sown as a secondary crop after the triticale harvest. In each trial one forage sorghum variety and one sweet sorghum variety were cropped.

Results from trials are shown in table 3 for main crops and in table 4 for secondary crops.

TABLE 3 **Sorghum (main crop) dry-matter yields, N uptake and efficiency**

Farm	**Type of sorghum**	**Fertiliser**	**N rate (kgN ha^{-1})**	**Yield Mg DM ha^{-1}**	**N uptake kg N ha^{-1}**	**N-efficiency %**	**Soil NO_3^- Index harvest/sowing**
PC01	Sweet	Test	0	7.29	70	-	1.07
		Urea	190	9.93	104	17.97	0.99
		Cattle manure		12.77	117	24.91	2.59
	Forage	Test		11.22	110	-	0.52
		Urea	190	8.56	101	-4.73	1.05
		Cattle manure		11.58	112	1.25	1.18
RE01	Sweet	Test	0	6.26	31	-	0.52
		Urea	120	9.81	50	15.77	0.46
		Pig manure		11.96	56	21.01	0.55
	Forage	Test	0	7.49	38	-	0.41
		Urea	120	10.48	50	10.09	1.01
		Pig manure		12.16	63	21.22	0.49

TABLE 4 **Sorghum (secondary crop) dry-matter yields, N uptake and efficiency**

Farm	Type of sorghum	Fertiliser	N rate (kgN ha^{-1})	Yield Mg DM ha^{-1}	N uptake kg N ha^{-1}	N-efficiency %	Soil NO_3^- Index harvest/sowing
BO01	Sweet	Test	0	6.29	156	-	0.68
	Forage	Test	0	7.58	156		0.64
RA01	Sweet	Test		5.60	67	-	3.59
		Urea	100	5.52	70	3.60	10.23
		Digestate		6.04	83	16.60	10.41
	Forage	Test		7.49	73	-	3.59
		Urea	100	10.48	73	2.51	10.23
		Digestate		12.16	80	9.98	10.41

Results from table 3 and 4 showed that higher dry-matter yields were obtained for forage sorghum, amounting to an increase of about 1 Mg ha^{-1} of dry-matter as compared with that obtained from sweet sorghum.

In farms where sorghum was sown as a main crop (table 3), plots fertilised with organic fertilisers (cattle manure for PC01 and pig manure for RE01) produced the highest dry-matter for both varieties of sorghum. Liquid manure seemed to facilitate the availability of nitrogen for plants. On the other hand, the efficiency of inorganic fertilisers such as urea depends on soil moisture, rains and irrigation. In this case, as no irrigation was applied and rains were fairly light over the period, the fertilisation effect was very low. The low production observed for PC01 was due to the laid down of the crop resulting in losses during harvest.

When Sorghum was sown as a secondary crop, it was observed that despite the fact that it is a drought-resistant species, if no irrigation is applied, the initial sprouting of the crop depends on rains, which in the months of June and July are very rare in the Po plain reducing dry-matter yields, as can be seen from table 4.

The N efficiency found was very low for all cases. The maximum was found for organic fertilisation, as explained above, possibly because water contained in manure or digestates contributed to making N available for the plants.

The comparison of the soil nitrate content did not reveal any change between sowing and harvesting times when sorghum was sown as a main crop. N accumulation, however, was found for fertilised sorghum sown after triticale (RA01). In this case N-uptake was very limited, and this resulted in low production as well as nitrate accumulation (Table 3 and 4) with the consequential soil leaching risk.

4 CONCLUSIONS

In general, organic residues guaranteed production levels similar to those obtained with mineral fertilisers. Results obtained showed that organic residues from energy conversion (i.e. digestates) can be a valuable nitrogen source for fertilisation, which plays a positive role in reducing the environmental and economic impact of the energy chains.

Triticale yields confirm that it is a valuable crop for producing biomass for biogas, and moreover, as any winter crop covering soil during the cold season, it prevents nitrates from leaching to water bodies. So far as the sorghum trials were concerned, it was shown that if sorghum is sown as a main crop, sustainable production can be achieved even without any irrigation. If, however, it is sown after triticale as a secondary crop, it is necessary to irrigate because otherwise yields can be fairly low, compromising rotation sustainability. In sorghum trials, the use of slurries and digestates contributed to the availability of N for the plants, increasing the N uptake and efficiency.

The trials discussed in this paper were used to validate a mathematical model for the estimation of variations in greenhouse gas emissions and carbon sequestration resulting from changes in soil use (in particular, conversion to energy crops and the use of organic residues).

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