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REDUCTION OF AGRONOMIC INPUTS IN SUNFLOWER (*Helianthus annuus* L.)

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SUMMARY

A two-year field study was carried out in a Mediterranean environment (Foggia, Southern Italy) to assess the effects of two soil tillage depths (conventional and minimum tillage) and three strategies of nitrogen (N) fertilization (organic, mixed, mineral) on the growth, biometric parameters, yielding and qualitative characteristics of sunflower cropped with durum wheat in a two-year rotation. The fertilizer treatments applied were: 100com, with Municipal Solid Waste (MSW) compost; 100mix, with organic N (MSW compost) and mineral N; 100slow, with a slow release organic-mineral fertilizer; 100min and 50min, with mineral N; unfertilized control (Contr).

The results obtained during the trial period have shown that the minimum soil tillage, MSW compost fertilization (as 100com and 100mix) and conservative practices were able to give good quantitative and qualitative responses. Furthermore, no increase of heavy metals has been found in the plots treated with MSW compost application.

Key words: **conventional and minimum tillage, MSW compost, quality, sunflower, yield**

INTRODUCTION

Over the years, soil degradation has become one of the most important problems in agriculture. Erosion, salinization, compaction and loss of organic matter are the main forms of soil deterioration. Addition of organic matter could be a way to improve soil structure and aeration, creating a better environment for plants growth. The organic matter content of soils can be increased by growing and plowing under green manure crops, or by plowing under organic residues such as manure, crop residues and composts of different origin. Among these materials, Municipal Solid Waste (MSW) is widely employed in many countries as compost. It is a new and renewable source of nitrogen and other nutrients. Furthermore, this method of use of MSW is also a disposal method of large amounts of biodegradable

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organic waste, able to minimize the negative effects on the environment. When MSW compost is applied to the soil, it can support plant growth, increase plant yield and also improve the physical, chemical and biological properties of soils (Giusquiani *et al.*, 1988; Giusquiani *et al.*, 1995; Serra-Wittiling *et al.*, 1996; Bazzoffi *et al.*, 1998; Bresson *et al.*, 2001; Convertini *et al.*, 2004) which are essential for sustaining soil productivity. Nevertheless, MSW compost can contain undesirable levels of heavy metals, such as lead, copper, zinc, cadmium, mercury and nickel, substances harmful to human and animal health.

On the other hand, farmers need to manage tillage systems, as a practice of soil conservation, to reduce nutrient losses by erosion and oxidation of organic matter, which is important as a source of nutrients and in improvement of soil physical and biological properties, all in order to obtain optimal crop growth (Maiorana *et al.*, 2003). Rational tillage systems may protect water resources, especially in arid and semi-arid regions, where the rainfall is usually scanty and unevenly distributed in time and space. Cambardella and Elliott (1993) indicated that traditional tillage can reduce soil organic C and N and disrupt soil aggregates, while no tillage or minimum tillage are more efficient in conserving moisture, controlling soil erosion and increasing C and N storage in the soil (Franzluebbers *et al.*, 1995).

In the light of these considerations, the objective of our study was to evaluate the possibility to reduce soil tillage depth and to employ alternative fertilizer sources instead of mineral ones in a sunflower (*Helianthus annuus* L.) crop that needs high nitrogen application for increased seed and oil yields (Baldini *et al.*, 1996; Tonev, 1996; Escalante *et al.*, 1998; Nanjundappa *et al.*, 2001) and good soil tillage (Bonari *et al.*, 1996; Sadras and Calvin, 2001).

MATERIALS AND METHODS

The site

The experiment was conducted in 2001 and 2003 in Foggia (Southern Italy, 41°27' latitude N, 15°36' longitude E, 90 m a. s. l.), in a typical area of Mediterranean environment.

The climate is classified as "accentuated thermomediterranean" (FAO UNESCO classification), with scant rains, mainly concentrated in the winter months.

The annual rainfall during the trial period was characterized by great variability between the years and among the months of each year. In fact, although the total rainfall in 2003 was higher than that in 2001 (571 mm and 455 mm, respectively, vs. 551 mm for the long-term average 1952-2000), there was a better rainfall distribution in the driest year, with more abundant rains during both vegetative and generative stages of sunflower growth (149 mm vs. 83 mm of 2003). Conversely, the average monthly temperatures were higher than the long-term average (+1.0°C) in 2001 (15.4°C) and similar in 2003 (15.3°C).

The soil is a silty clay Vertisol of alluvial origin, classified as typic chromoxerert, fine, mesic (Soil Taxonomy-USDA, 1975). Its main starting characteristics were as follows: total N=0.139%; available P=77 mg kg^{-1}; exchangeable K=1685 mg kg^{-1}; organic matter=2.32 %; pH=8.12.

Treatments and experimental design

Two soil tillage systems, conventional tillage at 40-45 cm deep (CT) and minimum tillage (MT), and three strategies of plants nitrogen (N) fertilization were managed in plots of 40 m^2, laid out in a split-plot design with three replicates. The optimal nitrogen dose for sunflower crop in the trial area (100 kg N ha^{-1}) has been distributed as:

1. Organic fertilization, with Municipal Solid Waste compost (100com);
2. Mixed fertilization, with 50 kg ha^{-1} of organic N (MSW compost) and 50 kg ha^{-1} of mineral N (100mix) and with Azoslow, a slow-release organic-mineral N fertilizer (100slow);
3. Mineral fertilization, with ammonium nitrate (100min).

These treatments were compared with a reduced level of mineral nitrogen fertilization, 50 kg N ha^{-1} (50min), and with an unfertilized control (Contr). The fertilizers were applied as following: 100com, 1 month before sowing; 100mix, 1 month before sowing, as MSW compost, and 70 and 56 days after sowing (DAS), in 2001 and 2003, respectively, as mineral N; 100slow, at the sowing-time; 100min, half at the sowing-time, half at 70 and 56 DAS; 50min, at the sowing time. Furthermore, all trial plots received 50 kg P_2O_5 ha^{-1} at the time of main soil plowing (fall) and an irrigation volume equal to the 80% of water stored in the soil layer 0-40cm, applied when the cumulative evaporation reached 90 mm.

The same MSW compost was used in both trial years. It was obtained by Cupello engineering through an aerobic transformation of Municipal Solid Waste by selective collecting, while Azoslow was made by ILSA factory. The mean chemical composition of MSW compost was: total N=0.147%; Cu=330 mg kg^{-1}; Zn=751 mg kg^{-1}; Pb=670 mg kg^{-1}; Ni=217 mg kg^{-1}; Cd=1.3 mg kg^{-1}; total organic carbon=13.75 g kg^{-1}; total extracted carbon=7.67 g kg^{-1}; humified organic carbon=2.51 g kg^{-1}; C/N=9.55. The composition of Azoslow was: total N=29%; organic N=5%; mineral N (as urea)=24%; total organic carbon=18%.

Sunflower (cv. Oliogen) was grown in two-year rotation with durum wheat and sown in 2001 and 2003, with a 50 cm row spacing and a theoretical plants density of 6.6 m^2.

Determinations

On one square meter of sunflower plants, taken randomly from each plot during the cropping cycle (52 and 37 DAS for 2001 and 2003, respectively), at the flowering stage (93 and 71 DAS) and at physiological maturity stage (128 and 106 DAS), the total dry weight (leaves, stalks, heads) and the leaf area index (LAI) were determined. At the harvest time (146 and 133 DAS for 2001 and 2003, respectively), on samples of 10 m^2 of sunflower plants, collected from each elementary plot, the main biometric characteristics (plants height, total, fertile, infertile diameter of heads) and the main yielding and qualitative parameters (yield, 1000-seed weight, hectoliter weight, protein and oil contents) were determined. To better understand the yielding performance as affected by the experimental treatments, the protein and oil yields (seeds yield per protein and oil contents, respectively) were also calculated.

Furthermore, three soil samples, collected from the 0-40 cm layers of the elementary plot of 100com and Contr at the beginning (t0) and the end (tf) of the experiment and later pooled in one sample, were taken for determination of heavy metals content (Zn, Cu, Ni, Cd, Pb) by atomic absorption spectrometry.

Statistical analysis

The data obtained during the trial period were subjected to the analysis of variance, using SAS statistical procedures (SAS Institute, 1999-2001). The differences among treatments were evaluated with the least significance difference (LSD) when two means were compared and with the Student-Newman-Keuls test (SNK) for more than two means compared. The Pearson correlation coefficients were used to compare yielding performance and some qualitative and growth parameters. All differences discussed are significant at the $P \leq 0.05$ probability level.

RESULTS AND DISCUSSION

Plants growth

During the whole cropping cycle of sunflower, the effects of soil tillage depth and N treatment on its growth capability were evaluated by means of the total dry weight of plants (leaves, stalks and heads) (Table 1) and of the LAI (Figures 1 and 2).

Table 1 shows that in the first trial year (2001), sunflower plants reached the significantly highest total dry weight until the flowering stage (93 DAS) with the minimum soil tillage, while no significant difference was observed at the maturity stage.

Significant differences were found also among N treatments, but only at 52 DAS, while during the following steps of cropping cycle there was no evident superiority of either treatment. The 100com and 100mix treatments presented, on the whole, interesting values, indicating a slow release of N from MSW compost, as suggested by Montemurro *et al.* (2005).

Unlike in the first year, the soil tillage in 2003 brought no significant difference in dry weight values during the sunflower cropping cycle.

The effects of the N treatments were statistically significant until the flowering stage, whereas no difference was found at the end of cropping cycle, because of a high mineralization which occurred during the summer periods, especially when there was no limit of water and organic matter (2.32%) in the soil, as suggested by Montemurro *et al.* (2002).

Table 1: Effects of experimental treatments on total dry weight (leaves, stalks and heads) of sunflower

	Total dry weight (g m^{-2})		
	Days after sowing		
	52	93	128
	2001		
Soil tillage			
Ct	37.75b	727.41b	790.32
Mt	62.93a	870.58a	816.17
N treatments			
100com	60.03a	748.88	754.75
100mix	50.74abc	796.01	772.17
100slow	54.68ab	863.42	776.29
100min	56.02ab	872.43	808.51
50min	43.69bc	721.27	830.64
Contr	36.87c	791.98	877.10
	Days after sowing		
	37	71	106
	2003		
Soil tillage			
Ct	33.65	540.80	775.00
Mt	33.79	473.78	802.22
N treatmants			
100com	32.54ab	527.90ab	781.28
100mix	32.16ab	569.00a	727.53
100slow	38.14a	531.72ab	726.06
100min	33.42ab	459.37ab	799.53
50min	38.50a	540.25ab	853.10
Contr	27.57b	415.52b	784.13

Within each column, the values followed by different letters are significantly different at $P \leq 0.05$.

Figures 1 and 2 show the effects of the experimental treatments on LAI from the early stage till maturity during 2001 and 2003, respectively.

In both years, all treatments achieved the maximum LAI at the flowering stage, with mean values ranging from 3 to 4 in the first year and about 3 in the second year. The latter value can be considered the best, because, as reported by Merrien (1988), LAI at flowering should be less than 3. In fact, an excessive plant development can cause early senescence during the grain-filling stage, due to self-shading of the lower leaves by the upper ones.

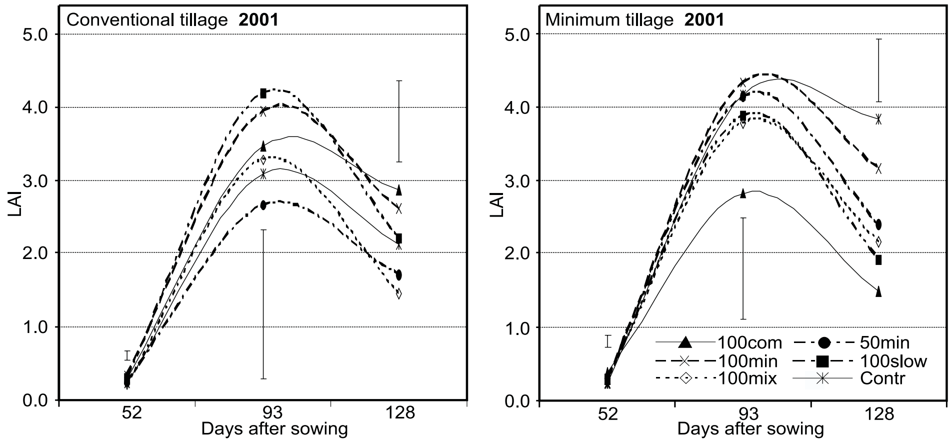

Figure 1: Leaf area index (LAI) of sunflower plants as affected by experimental treatments. Bars represent the LSD at P=0.05 for mean value comparison at each sampling data

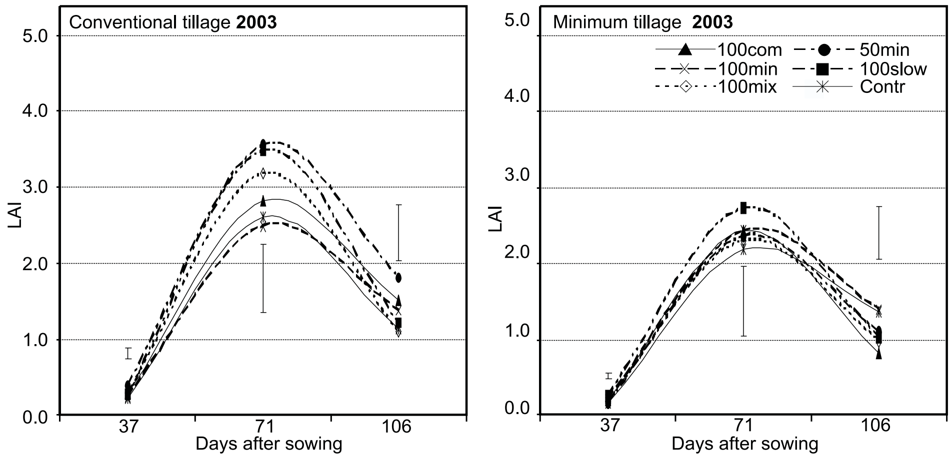

Figure 2: Leaf area index (LAI) of sunflower plants as affected by experimental treatments. Bars represent the LSD at P=0.05 for mean value comparison at each sampling data.

With reference to the experimental treatments, it is very difficult to choose the best soil tillage, because of the opposite behavior showed in the two trial years (in 2001 the lowest mean values of LAI at 93 DAS were reached with conventional tillage, in 2003 with minimum tillage). A lack of clear trend was also observed for the N treatments. However, in both years, 100slow seemed to be the best treatment, since this kind of fertilizer released the nitrogen to plants at the peak of their vegetative growth.

Very interesting were the responses of the unfertilized treatment (Contr) in both growth parameters; in fact, it often showed low values of dry weight and LAI at the beginning of the cropping cycle, but progressively avoided the differences with other treatments.

Table 2: Correlation coefficients among yielding, qualitative and growth parameters of sunflower

	Seed yield		Oil content		Protein content	
Seed yield	-		0.3324	**	-0.2844	*
Oil content	0.3324	**	-		-0.5464	***
Protein content	-0.2844	*	-0.5464	***	-	
LAI at flowering	0.4294	***	0.4182	***	-0.2445	*
Dry matter at flowering	0.3972	***	0.3285	**	-0.0896	ns

*, **, ***=Significant at the P<0.05, 0.01 and 0.001 levels, respectively, according to Pearson correlation coefficients; n.s.=not significant.

On the whole, positive and significant correlations were found between the growth parameters (LAI and dry matter at flowering stage) and seed and oil yields (Table 2), indicating that the vegetative stage strongly affected the sunflower yielding performance. Conversely, there was a negative significant correlation between LAI at flowering and seeds protein content.

Table 3: Effects of years and experimental treatments on the main biometric parameters of sunflower

	Plants height (cm)	Diameter heads (cm)			Heads fertility (%)
		Total	Fertile	Sterile	
Year					
2001	127.86b	15.20b	12.60b	2.59a	82.90b
2003	140.65a	18.13a	17.62a	0.51b	97.15a
Soil tillage					
Ct	134.57	16.95a	15.43a	1.53	90.36
Mt	133.94	16.38b	14.80b	1.58	89.69
N treatments					
100com	134.26	16.54	15.00	1.54	90.08
100mix	134.55	16.17	14.69	1.48	90.39
100slow	135.46	16.57	14.91	1.66	89.32
100min	132.09	17.04	15.51	1.53	90.19
50min	134.58	16.86	15.37	1.49	90.68
Contr	134.59	16.79	15.11	1.68	89.32

Within each column, the values followed by different letters are significantly different at P≤0.05.

Biometric, yielding and qualitative parameters

Table 3 shows that the best, statistically significant results of the biometric characters were observed in the second trial year (2003), except the sterile heads diameter, that reached highest values in 2001.

Regarding the soil tillage management, reductions were obtained with the minimum soil tillage only in the total and fertile diameters of the head.

Conversely, N treatments did not bring any significant difference in either of the biometric parameters examined.

Table 4: Effects of years and experimental treatments on the main yielding and qualitative parameters of sunflower

	Seed yield (t ha^{-1})	1000-seed weight (g)	Hectoliter weight (kg)	Protein			Oil
				(%)	(t ha^{-1})	(%)	(t ha^{-1})
Year							
2001	3.20a	52.43b	39.71b	19.66b	0.63b	52.45a	1.68a
2003	2.90b	60.41a	42.30a	23.61a	0.68a	47.36b	1.37b
Soil tillage							
Ct	3.09	58.68a	41.05	21.66	0.67	50.14	1.56
Mt	3.00	54.16b	40.59	21.61	0.65	49.67	1.49
N treatments							
100com	3.00	57.40	40.91	21.77	0.65	49.65	1.50
100mix	2.97	56.77	41.30	21.48	0.63	50.09	1.49
100slow	3.13	56.49	41.26	22.41	0.70	49.84	1.57
100min	3.05	54.94	41.36	21.64	0.65	49.83	1.53
50min	3.11	56.33	40.72	21.91	0.68	50.40	1.57
Contr	3.03	56.59	40.48	20.58	0.63	49.65	1.50

Within each column, the values followed by different letters are significantly different at $P \leq 0.05$.

The effects of the years, soil tillage depths and nitrogen treatments on the most important quantitative and qualitative parameters of sunflower are reported in Table 4. The yields of seed and oil were significantly higher in the first year, while protein yield was better in 2003, because of the inverse correlation that links quantitative and qualitative characteristics. Our results confirm this finding, since negative and significant correlations were found between seed yield and oil content on one side and protein content on the other (Table 2).

In the same year (2003), the 1000-seed weight and the hectoliter weight were also statistically highest.

The decrease in seed yield (by about 9.4%) observed in 2003 can be attributed to the negative effect due to the lowest rainfall received by sunflower plants during vegetative cycle and especially at the flowering stage (83 and 149 mm in 2003 and 2001, respectively), that affected the growth of plants and, consequently, their performance.

Conversely, the soil tillage management did not significantly affect seeds yield (3.09 and 3.00 t ha^{-1}, for CT and MT, respectively) and the other parameters, except the 1000-seed weight which was higher with the conventional tillage (58.68 g vs. 54.16 g in minimum tillage).

The positive response of sunflower to minimum tillage is very interesting, pointing out that this agronomical practice can be considered a useful alternative to conventional tillage under Mediterranean conditions, both from the economic and the environmental aspect. Similar results were found by López-Bellido *et al.* (2000), indicating that continuous no-tillage does not affect sunflower yield. Contrary to this, some studies carried out on different crops in the same (Maiorana *et al.*, 2001) or in other environments (Giambalvo *et al.*, 1999; Halvorson *et al.*, 2000) found that yield level and quality obtained with minimum tillage are lower than those following the conventional one. Consequently, many parameters such as soil organic matter content, temperature and water regimes, could be involved when different soil tillage methods are adopted.

Regarding the effects of the N treatments, these have shown the same trend in all parameters examined, without significant differences (Table 4). These results showed the effectiveness of MSW compost, applied alone (100com) or combined with mineral N (100mix), and then its capability to have a nutritional function similar to that of mineral treatments (50min and 100min), according to Montemurro *et al.* (2005). Good responses were also obtained in the 100slow treatment.

It was found for the growth parameters of sunflower that the performance of the unfertilized treatment (Contr) was more or less alike to the performances of the other treatments. The lack of significant differences could be attributed to the soil fertility of the trial site, characterized by high levels of soil organic matter and total N, as well as to the capability of sunflower plants to efficiently utilize the mineralized organic N by means of their deep and branched root system (Blanchet *et al.*, 1987; Baldini *et al.*, 1996; Connor and Sadras, 1992). In fact, under conditions of our trial, the relatively high temperatures of spring-summer months and the sufficient soil water content (rains and watering) have accelerated the mineralization processes of organic matter allowing good yields in the unfertilized control. On the other hand, these performances have also caused a higher N deficit in the soil, as found by Montemurro *et al.* (2005), pointing out the control's notsustainability over time from the agronomic point of view.

On the whole, the obtained results seem to be very interesting, having confirmed the trend already observed in the growth parameters, *i.e.*, the effectiveness of minimum tillage and of MSW compost as N source.

Soil heavy metals content

The total contents of zinc (Zn), copper (Cu), nickel (Ni), cadmium (Cd) and lead (Pb) for the treatments 100com and control are shown in Table 5.

No significant difference in these elements could be found in the 100com plots at the end of the two-year experiment. Furthermore, the contents of Zn, Cu, Ni, Cd and Pb were considerably under the maximum admissible concentration (MAC), according to Yankov and Tahsin (2001). Only the Cd content showed higher values, but it was so since the beginning of trial (t0) and in the100com treatment and the unfertilized control, pointing out that the experimental field had a high Cd level before the MSW compost application.

The lack of increase in heavy metals could be due to the dilution of these elements present in the MSW compost when applied to the soil. These results confirm that the presence of trace elements in MSW compost should not affect soil application of this material, as suggested by Logan *et al.* (1999).

Table 5: Effects of Contr and 100com treatments on heavy metals content at the beginning (t0) and the end of sunflower cropping cycle (tf)

Chemical determination	Time	Treatments		MAC*
		Contr	100com	
Zinc (Zn) (mg kg^{-1})	t0	125.87	102.45	270
	tf	105.22	107.78	
Copper (Cu) (mg kg^{-1})	t0	104.67	111.66	360
	tf	114.99	97.68	
Nickel (Ni) (mg kg^{-1})	t0	41.41	45.36	250
	tf	53.37	49.31	
Cadmium (Cd) (mg kg^{-1})	t0	6.02	6.55	2.00
	tf	6.42	5.01	
Lead (Pb) (mg kg^{-1})	t0	51.04	54.34	80
	tf	55.33	62.37	

* MAC: maximum admissible concentration (according to Yankov and Tahsin, 2001).

CONCLUSIONS

The results obtained in this research have shown the following.

1. Minimum tillage did not affect negatively sunflower performance, ensuring yields and quality similar to those obtained with conventional tillage. Minimum tillage may thus be an important alternative to the deep soil plowing, both from the economic and environmental points of view.
2. The application of MSW compost allowed good yields and quality, even without an additional mineral N fertilization. Also, it did not increase the soil heavy metals content. Furthermore, its application could improve the soil organic matter and minimize the problems related to waste disposal, to save the productive costs and to reduce the environmental pollution caused by a large application of mineral fertilizers.

It is planned to continue this trial on other crops in the same experimental field in order to assess the possible effects of minimum tillage on the yielding capability of crops and, above all, to determine the long-term effects of MSW compost on both soil properties and heavy metals content.

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REDUCCION DEL INPUT AGRICOLA EN UN CULTIVO DE GIRASOL (*Helianthus annuus* L.)

RESUMEN

Una investigación bienal se ha realizado en ambiente mediterráneo (Foggia, en el sur de Italia) con el fin de evaluar los efectos ejercidos por el dos modalidas de aradura del terreno (convencional y no labrado) y tres tipos de abono (mineral, orgánico y misto) sobre el rendimiento de semillas y la calidad y los parametros de crecimiento en un cultivo de girasol en rotación bienal con trigo duro.

Los fertilizantes utilizados han sido: 100com, con Residuos Sólidos compuestos de basura Urbana seleccionada; 100mix, con nitrógeno (N) orgánico (RSU abono) y N mineral; 100slow, con N orgánico- mineral a lento efecto; 100min, con N mineral; 50min, con N mineral. Se han comparado todos estos tratamientos con un control (Contr) sin abono en parcelas de 40 m^2 cada una, extendidas en split-plot dibujo experimental con tres repeticiones.

Los resultados obtenidos demuestran que sea el cultivo mínimo del suelo, sea el abono orgánico compuesto de basura sólidos urbana (ambos 100com y 100mix), han sido capaces de dar buenos resultados de producción y calidad sin aumentar el contenido de metales pesados en el terreno.

RÉDUCTION DES INPUTS AGRONOMIQUES DANS UNE CULTURE DE TOURNESOL (*Helianthus annuus* L.)

RÉSUMÉ

Une expérimentation menée en conditions de plein champ sur deux années à Foggia (Sud de l'Italie), a été conduite pour évaluer l'effet de deux profondeur du labour (labour traditionnel et minimum) et de trois stratégies de fumage (minéral, organique et mixte) sur le rendement, la qualité et les paramètres de croissance du tournesol, cultivé en rotation biannuelle avec le blé dur.

Les traitements de fertilisation azotée employés sont les suivants: 100com, avec compost dérivé de Déchets Solides d'origine Municipale (DSM compost); 100mix, avec azote (N) organique (DSM compost) et N minéral; 100slow, avec engrais organique-minéral à lent effet; 100min, avec engrais minéral; 50min, avec engrais minéral. Tous les traitements ont été comparé a un control non fertilisé (Contr). Le dispositif expérimental adopté été en split-plot, avec trois répétitions dans des parcelles de 40 m^2 chacune.

Les résultats ont montré que tant la profondeur minimum du labour comme l'administration de DSM compost (100com et 100mix) comme source d'azote ont montré un effet positif sur le rendement et la qualité du tournesol. En outre, l'administration de DSM compost n'avait pas augmenté le contenu des métaux lourds au niveau du sol.