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Vol.2
ISSN : 2356-5608
Conférence Internationale des Energies Renouvelables (CIER'13) Sousse, Tunisie - 2013

Evaluating pre-crops and organic fertilizers for effects on soil properties and organic onion growth and yield in eastern Tunisia

(*Pre-crops and organic fertilizers effects on soil and onion)*

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***Abstract*—** *Soil fertility is a critical issue in organic farming which attempts to close the nutrient cycle and enhance beneficial biological interactions and processes. Soil building crops and organic fertilizers usually contribute to improved soil properties and crop productivity. The present research is a contribution to evaluate the effects of pre-crops and organic fertilizers on soil properties and onion growth and yield in the context of Tunisian organic agriculture. It mainly addresses two questions: what is the best pre-crop that can be used by organic farmers? Can the newly introduced compost tea in Tunisian organic agriculture substitute commercial organic fertilizer? In order to get answers to these questions we carried out field experiments in East Tunisia. Three pre-crops (fennel, pea and faba bean) and two organic fertilizers (compost tea, CT and commercial fertilizer, CF) were tested for their effects on organic onion growth and yield and soil properties. Results showed that all simple treatments (pre-crops and fertilizers) had no significant effects on soil organic matter content. However, the fennel pre-crop coupled with the CF showed significant increase in soil organic matter content. Soil N, P and K contents were greater after fennel, pea and faba bean, respectively. While the treatments interaction had no significant effect on soil N, the pea pre-crop coupled with CF gave the highest soil P and K contents. As for treatments effects on main crop, under the conditions of the present study, the pre-crops and organic fertilizers effects on onion quality and yield were clearly shown to be modest or insignificant. Although most of the studied properties responded more to the CF than the CT application, the latter performed well. This suggests that the CT can be a profitable substitution to the CF in Tunisian organic agriculture.*

Keywords*— *soil fertility; compost tea; commercial fertilizer; pre-crops; organic onion; Tunisia

I. INTRODUCTION

Organic agriculture is developing rapidly and its share of agricultural land and farms continues to grow in many countries (Yussefi and Willer, 2007). In Tunisia, the organic agriculture started during the eighties by private initiatives and experienced a slow development until the years 1997-1998. Then, a national strategy based on severalcomponents including regulation, research, training,extension, organization, structure and encouragement was set up. This contributed to a spectacular development and a significantevolutionof this sector. According to the General Direction of Organic Agriculture in Tunisia (2012), almost 178 521ha are currently managed organically yielding a total organic production of 233 000tons (against 9077 tons in 2002).

Nevertheless, many organic farms in Tunisia have poor soil fertility (low organic matter content, low biological activity and poor structure). The main problems related to the improvement of soil fertility are the difficulties to introduce the green manure in the rotation, to train farmers for the compost management from different organic matter sources and to find authorized organic fertilizers in sufficient quantity (Ben Kheder, 2004).Therefore, numerous researches were carried out to evaluate soil fertility building techniques in organic systems such as pre-crops and organic fertilization by compost tea and commercial organic fertilizers.

Soil fertility-building crops have been reported as a way to reduce inputs, improve soil fertility and subsequent crop

production and quality. For instance, Sincik (2008) found thatpotatoes following green manure legume pre-crops produced approximately 36% to 38% higher tuber yields compared with potatoes following winter wheat. Similarly, Nuruzzamanet al. (2004) reported that wheat following white lupin, field pea and faba bean used as pre-crops had 30 %, 61 % and127 %, respectively more dry matter than wheat following wheat. They concluded that faba bean, which was the best of the species tested in promoting subsequent wheat growth, appears to be an excellent phosphorus-mobilizing legume crop for use in rotations with wheat.

Interest in organic teas for use in agriculture and horticulture has grown rapidly during the last decade. Certain liquid extractions of manures or composts, at various stages of decay, can supply plants with at least four major benefits: a source of plant nutrients; a source of beneficial organic compounds, an ability to suppress certain plant diseases; and as a way to build soil structure when applied as a drench (Merrill and McKeon, 2001).However, the effectiveness of compost extracts appears to depend on many factors including method of preparation, extraction time, compost type and crop to which they are applied (Welke, 2001).

The present study is part of a long term trial initiated and coordinated by the Mediterranean Agronomic Institute of Bari (MAI-Bari) within the framework of a Master research program involving four Mediterranean countries namely Italy, Morocco, Tunisia and Turkey. Its objective is twofold: (i) to evaluate the effects of three pre-crops usually used by organic farmers in Tunisia on some selected soil chemical and biological properties as well as on organic onion crop quality and yield. (ii) to evaluate the effectiveness of relatively newly introduced compost tea in Tunisian organic agriculture compared to commercial organic fertilizer.

II. MATERIAL AND METHODS

2.1 Experimental site and treatments description

The experiment was carried out at the experimental field of the Technical Center of Organic Agriculture located in Sousse region in the Center East of Tunisia (35°51'32" N -10°35'38" E).The region is characterized by a Mediterranean climate with humid mild winter and hot dry summer. The yearly precipitations vary from 350 to 400mm and are mainly occurring between October and April. The annual average temperature ranges from 16 to 19 °C, with a maximum recorded in July and a minimum recorded in January.

The experimental design was a split block design with four replications and two factors: pre-crops and fertilizers. Each subplot was of 32 m^2. Treatments include three pre-crops (fennel, pea and faba bean) as well as a fallow used as control. The faba bean (*Viciafaba*) was used as green manure. fennel (*Foeniculumvulgare*), variety Romanesco, was considered asfarmer's choice (commercial crop). Peas (*Pisumsativum*), variety Douce deProvence, was chosen as commercial leguminous. For fertilization, a compost tea (CT) and a commercial organic fertilizer (CF) were used (**Table 1**).The CT was extracted from animal manure compost under aerobic conditions. The water/compost ratio was 2.5/1 with continuous aeration through an air pump. The duration of tea extraction was five to six days, and the extract was applied directly by drip system.

On September 29, 2009, sowing of faba bean and peas, and transplantation of fennel were done. Fennel was sown in nursery on August 27, 2009. The harvest started on November 23, 2009 until January13, 2010. Manual weeding and hoeing were done twice for peas and fennel plots. Weeds between plots were left in order to increase biodiversity in the experimental field. Pre-crops were incorporated on January 27, 2010. The incorporation of faba bean was done during the full blossoming. Peas and fennel were completely harvested before incorporation. As for onion sowing, it took place on November 20, 2009 in nursery. Then, the transplantation was made on January 27, 2010. The spacing was 0.8/0.25 m (20000 plants/ha). The weeding was done three times during the crop growth, then, natural vegetation was left to protect onion plants from sun damages and to increase biodiversity.

2.2 Sample analysis

2.2.1 Soil analysis

Soil pH was determined in 1:2.5 soil water (weight/volume) suspensions, using a glass electrode pH-meter. Total soluble salts were estimated in the soil saturation extract and cations were measured by using the electrical conductivity meter (value expressed in ms/cm).The soil salinity was evaluated according to the conversion: 1ms/cm^3 = 0.7 g/l. Soil carbon content was analyzed by the Walkey and Black method (Grewling and Peech, 1960). Available phosphorus was determined according to modified Olsen method and based on the extraction of Phosphor by Sodium Bicarbonate (Pauwels et al., 1992).Total nitrogen was analyzed by "Modified kjeldahl method ". This method is based on the Kjeldahl mineralization but the catalyst used is the Titan dioxide instead of Selenium.

2.2.2 Plant analysis

Numerous morphological observations were made in order to determine some agronomic parameters related to the weight and diameter of the main head, the bulbing index (which is the ratio: bulb diameter/crown diameter) and the yields. The chemical parameters evaluated were total nitrogen content using Kjeldahl method, total phosphorus content determined by colorimetry and other major elements (K, Na, Ca) using a flame spectrophotometer.

2.2.3 Statistical analysis

Data analysis was done using the SAS program (Statistical Analysis Software) by the ANOVA analysis. Mean comparison was made with Duncan test at 5%.

III. RESULTS AND DISCUSSION

3.1 Soil properties

Table 2 reports the simple and the interaction effects of various treatments on some selected soil chemical properties. The results showed significant (p=0.05) simple effects of pre-crops and organic fertilizers on all studied soil properties except for OM content. It can be seen that for soil N content, there are significant differences between soil building crops. In fact, soil nitrogen content in fennel gave a higher N content than other pre crops. This is in contradiction with what was found by Bahouaoui(2008) and Jamea (2004) who reported that legume species showed significant higher values of soil available nitrogen than other species after their incorporation because they produced high amounts of dry biomass during the previous season.

By comparing pre-crops treatments to fallow it can be seen that plots grown after faba bean have the highest P and K contents. The highest N content was recorded for plots grown after fennel pre-crop. By considering all the studied soil properties, one may conclude that faba bean is the best pre-crop compared to fennel and pea. As for organic fertilizers, results showed that the CF performed better than the CT regarding OM, K and P soil contents. However, the usage of this fertilizer resulted in higher soil salinity and pH compared to the CT. For N soil content there was no significant difference between the two organic fertilizers. Nevertheless, the soil fertilized by commercial fertilizer tends to give slightly lower soil nitrogen content than fertilized by compost tea. Similar results were found by Elshokary (2007), Bahouaoui(2008) and Guenichi(2009) when the same pre-crops and fertilizers were used respectively on potato, zucchini and tomato crops.

The statistical analyses showed significant interaction between soil building crops and organic fertilizers used in the experiment regarding soil pH, EC and organic matter (**Table 2**). Soil pH in the plots grown after fennel as pre-crop and fertilized by commercial fertilizer is slightly higher than the other treatments. The statistical analysis shows significant interaction between pre-crops and fertilizers used in the experiment. Soil EC in the plots grown after fennel as pre-crop and fertilized by CT or CF was higher than the other treatments. The plots grown after control as pre-cop and fertilized by compost tea had the lowest EC values. As for soil OM, results showed that plots grown by pea and fennel and fertilized by CF gave higher organic matter contents in the soil. This result can be explained by the fact that the CF has higher organic matte content than the CT.

The statistical analysis of treatments effects on soil phosphorus showed significant interaction between the pre-crops and the fertilizers used in the experiment. The soil P content in the plots grown after pea as pre-crop and fertilized by CF was higher than all other treatments. Similar results were found by Bahouaoui (2008).

Soil K content showed significant interaction between pre-crops and fertilizers used under different treatments as shown in **table 2**. K values were higher for the plots grown after pea pre-crop and fertigated by the CF, probably because the CF has a higher K content than the CT. On the other hand, the lowest value was recorded for plots grown after fennel and fertigated by the CT. This is in agreement with what was found by Elshokary (2006), Bahouaoui(2008) and Guenichi (2009) who reported that legume species showed a significant difference of soil potassium.

3.2 Onion quality and yield

At harvest, onion bulbs were classified into three categories according to the bulb diameter: Category(1): 40 to 60 mm; Category (2): 60 to80 mm ; Category (3): more than 80 mm. Themajority of bulbs were found to be from category 3. No significant interaction (p=0.05) between fertilizers and pre-crops was found concerning bulb categories. Moreover, neither pre-crops nor organic fertilizers treatments had significant effect on bulb categories.

Other measures of onion quality also reflected a general lack of a treatment response (**Figures 1, 2**). Hence, the effects of tested variables (pre-crops and fertilizers) or their interaction on bulbing index and bulb weight were not significant (p=0.05). Nevertheless, onion planted after fennel seems to give slightly lower bulbing index than those planted after pea or faba bean pre-crops. Moreover, onion planted after green manure tends to give slightly higher bulb weight than the other pre-crops. As for fertilizers effect, the plants fertigated by the CF seem to give slightly higher bulbing index than those fertigated by the CT. Guenichi(2009) reported similar results for tomato crop.

The effect of various treatments on bulb chemical characteristics was assessed by determining Nitrogen, Phosphorous and Potassium contents on dry samples as well as the ascorbic acid (vitamin C) content which was determined on fresh fruits. The results summarized in **table 3** showed that statistically, the simple effects of pre-cropson fruit nitrogen content were not significant. However, onion planted after fennel tends to give slightly higher nitrogen content than the other treatments. As for fertilizers effects, the N uptake was significantly higher in plants fertigated by commercial fertilizer than those fertigated by compost tea. Besides, the statistical analyses showed no significant differences for P content between soil building crops. However, onion grown after faba bean seems to have slightly lower P content than other treatments. Moreover, onion plants fertilized by commercial fertilizer and by compost tea did not have significant differences regarding bulb P content. These results are in agreement with those found by Bahouaoui (2008) with

zucchini crop. As for K bulb content the statistical analysis showed significant differences, between pre- crops and between fertilizer types and no interaction was found between soil building crop and fertilizer. Plots grown after control, fennel and pea gave lower potassium content than faba bean. Similar results were recorded by Elshokary (2007) and Bahouaoui (2008). The compost tea treatment gave significantly higher bulb K content than commercial fertilizer.

As for bulb vitamin C content, the results showed that there were no significant differences neither between pre-crops nor between fertilizers as simple or interaction treatments. Nevertheless, the plants grown after legumes tend to give slightly higher vitamin C content in onion fruit than all other treatments. Plants which were fertilized by CT or CF presented the same vitamin C content in onion bulbs (**Table 3**).

Regarding treatments effects on onion yield, the results showed no significant interaction between the fertilizers and pre-crops (**Table 4**). Yield where the green manure was used as pre-crop was found slightly higher than all other treatments. Moreover, the statistical analysis of total yield in onion crop showed no significant differences between compost tea and commercial fertilizer. However, plants fertigated by CF tend to be slightly lower than those fertigated by compost tea. Similar results were reported by Hewady (2006). He stated that the CT had a great effect on yield for zucchini crop.

The marketable yield (% in relation to total yield) was computed for each treatment. The results showed no significant interaction between the pre-crops and the fertilizerstreatments (**Table 4**).Nevertheless, the pre-crops simple effects were significant on onion marketable yield. This was especially seen in the case of green manure plots which presented the highest marketable yield.

IV. CONCLUSION

Through the present study we investigated the simple and the interaction effects of three pre-crops (fennel, faba bean and pea) and two organic fertilizers (compost tea and commercial fertilizer) on some selected soil properties and organic onion quality and yield. In general, tested treatments showed significant effects on some soil and onion properties and had moderate or insignificant effects on some others.

Total yield was unaffected by all treatments and there was no interaction effect between pre-crops and fertilizers. The marketable yield, however, was positively affected in the case of plots grown after faba bean.

As for organic fertilizers effects, results showed that most of the soil and plant studied properties responded more to the commercial fertilizer than the compost tea fertilization. However, the results obtained with the CT were close to those obtained with the CF for most of studied soil and onion properties. Thus, in the light of the significant performance of the CT, further studies aimed at promoting CT usage in Tunisian organic agriculture are desirable.

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TABLE I

Properties	Compost tea	Commercial fertilizer
Organic carbon %	0.3	40
Total N %	0.5	4
Total P %	0.4	3
Total k %	0.7	3

TABLE II

Treatment	Soil property					
	pH	EC (dS/m)	OM (%)	N (ppm)	P (ppm)	K (ppm)
Pre-crops						
Fennel	8.1 (a)	2.6 (b)	3.5 (a)	2233.0 (a)	134.9 (c)	634.0 (d)
Faba bean	7.9 (bc)	2.1 (a)	3.2 (a)	2077.5 (b)	197.3 (a)	818.4 (a)
Pea	8.1 (ab)	2.7 (b)	3.5 (a)	1699.7 (c)	201.2 (a)	701.8 (c)
Fallow	7.8 (c)	2.2 (c)	3.4 (a)	1724.8 (c)	183.2 (b)	738.9 (b)
Organic fertilizers						
CT	7.9 (b)	2.4 (b)	3.3 (b)	1980.1 (a)	173.7 (b)	661.2 (b)
CF	8.1 (a)	2.8 (a)	3.5 (a)	1887.4 (a)	184.7 (a)	785.4 (a)
Pre-crops x Organic fertilizers						
Fennel CT	8.08	2.20	3.22	-	120.46	551.20
Fennel CF	8.11	3.22	3.80	-	149.38	716.77
Faba bean CT	7.81	2.67	3.17	-	196.67	820.27
Faba bean CF	8.09	3.11	3.22	-	197.67	816.55
Pea CT	8.11	2.59	3.30	-	195.90	578.40
Pea CF	8.07	2.7	3.71	-	206.49	825.2
Fallow CT	7.84	2.14	3.60	-	181.68	694.7
Fallow CF	7.88	2.27	3.31	-	148.8	783.12

TABLE III

Treatment	Bulb chemical properties			
	N (ppm)	P (ppm)	K (ppm)	Vitamin C (mg/100 ml)
Pre-crops				
Fennel	2.19 (a)	34.62 (a)	173.50 (b)	18.30 (a)
Faba bean	2.08 (a)	34.37 (a)	175.00 (a)	18.48 (b)
Pea	2.08 (a)	34.12 (a)	173.37 (b)	18.59 (a)
Fallow	2.09 (a)	34.87 (a)	172.87 (b)	18.37 (a)
Organic fertilizers				
CT	2.09 (b)	34.31 (a)	173.06 (b)	18.52 (a)
CF	2.13 (a)	34.68 (a)	174.31 (a)	18.34 (a)

TABLE IV

Treatments		**Total yield**	**Marketable yield** (%)
Pre-crops	Fennel	1.98 (a)	92.87 (b)
	Faba bean	2.15 (a)	94.62 (a)
	Pea	1.95 (a)	93.62 (ab)
	Fallow	2.00 (a)	94.5 (ab)
Organic fertilizers	CT	2.14 (a)	94.30 (a)
	CF	1.88 (a)	93.43 (a)

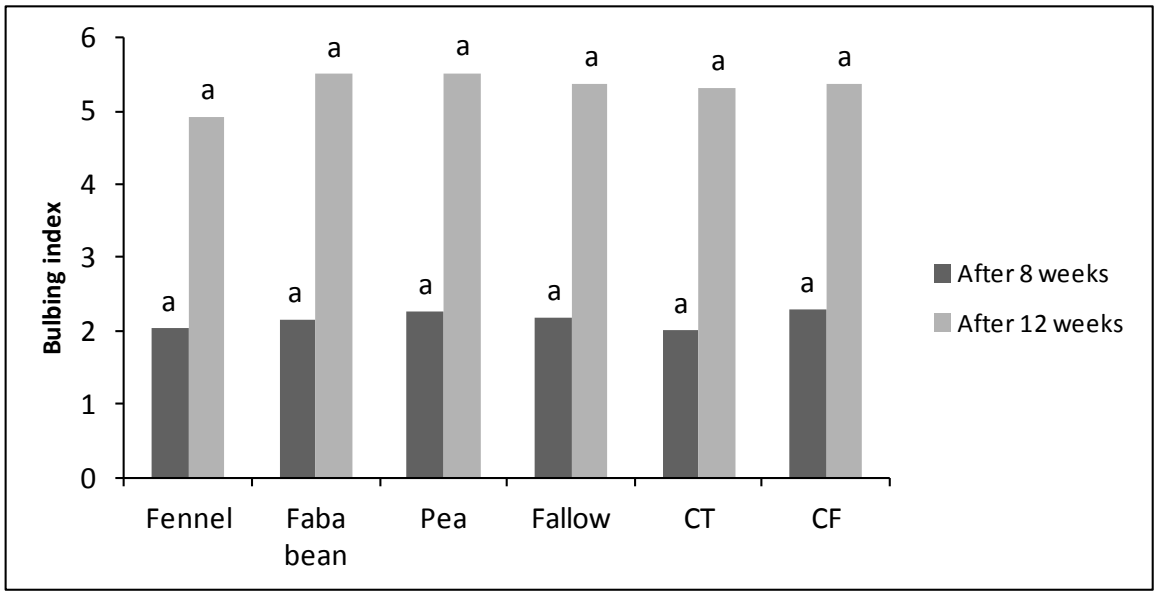

Figure 1

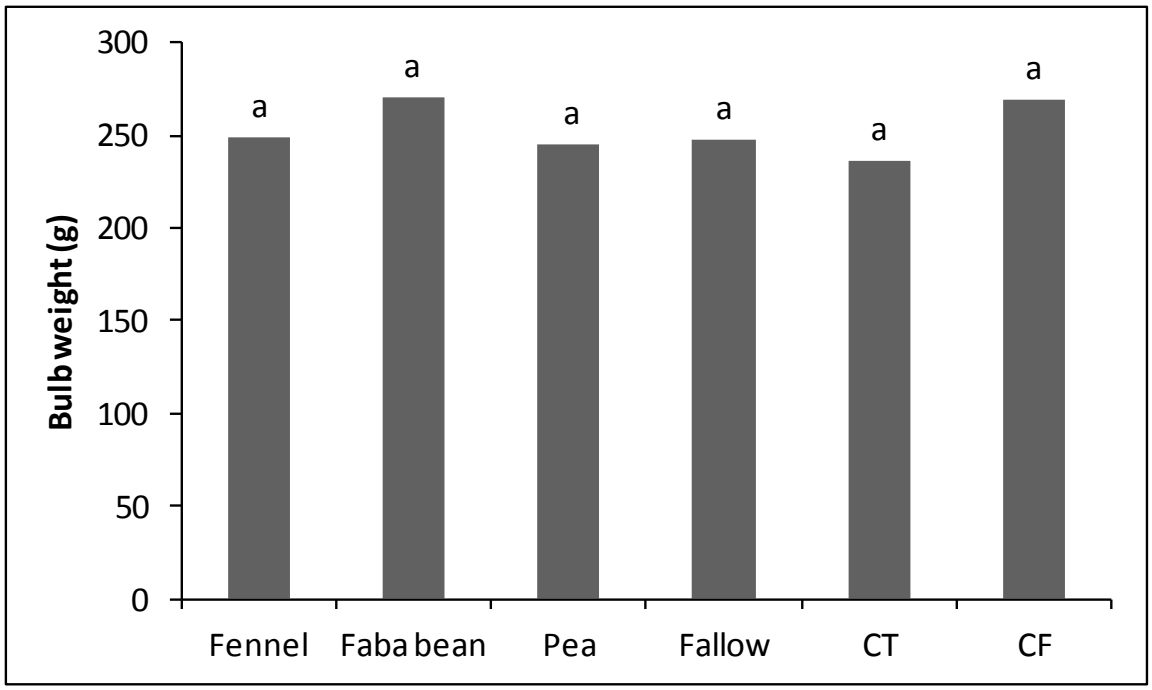

Figure 2

Table 1. Compost tea and commercial fertilizer (Grobel) properties and mineral elements content (mg Kg^{-1})

Table 2. Simple and interaction effects of pre-crops and organic fertilizers on soil chemical properties. Means with the same letters are not significantly different at 5% upon Duncan multiple range test

Table 3.Effects of pre-crops and organic fertilizers on onion bulb chemical properties. Means with the same letters are not significantly different at 5% upon Duncan multiple range test.

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Table 4. Effects of pre-crops and fertilizers on onion total and marketable yields. Means with the same letters are not significantly different at 5% upon Duncan multiple range test.

Figure 1.Effect of pre-crops and organic fertilizers on onion bulbing index. Means with the same letters are not significantly different at 5% upon Duncan multiple range test. CT: compost tea; CF: commercial fertilizer.

Figure 2.Effect of pre-crops and organic fertilizers on onion bulb weight. Means with the same letters are not significantly different at 5% upon Duncan multiple range test. CT: compost tea; CF: commercial fertilizer.