LIFE Project Number

<LIFE05 TCY/MA/000141>

FULL PROJECT TITLE

'Design and Application of an Innovative Composting Unit for the Effective Treatment of Sludge and other Biodegradable Organic Waste in Morocco, MOROCOMP'

Task 4:

Evaluation of compost products as soil improvers

Deliverable 14

Report on the phytotoxicity tests

Report on the effects of compost on tested cultivations

June 2008

Summary

Within the framework of MOROCOMP project, an innovative composting system for the effective treatment of sludge and other biodegradable organic waste was designed, constructed, set up and operated at the experimental station SEMVA (Station Experimentale de Mise en Valeur Agricole) in Zemamra in the greater area of Doukkala region in Morocco. Processing sludge and other BOW into the bioreactor results in the production of compost which can have various agronomic uses e.g. fertilizer, soil improver. However, compost that uses raw material which originates from sludges can be potential harmful to human health as well as to the environment when applied on land. Therefore this report aims to evaluate the suitability of the produced composts (as presented in Deliverable 13) as soil amendments and/or fertilizers for agricultural practices. Phytotoxicity is a term used to define the intoxication of living plants by substances present or produced in the growth medium, when these substances are taken up and accumulated in plant tissue. Phytotoxity is a well-known and applied method for determining whether composting end products may affect plant health and growth as well as soil properties.

Laboratory phytotoxicity tests were carried out to evaluate whether the produced composts, using the demonstration composting system that was designed for this project, could enhance seed germination or inhibit it due to the presence of phytotoxic compounds. Phytotoxicity is related to the maturity of the produced compost since mature composts are less likely to cause damage to plant growth. The degradation of the organic matter in composts is maintained after their production but at a very reduced rate. The organic compounds of a good quality compost undergo slow biological conversion into less aggressive and more stable substances minimizing the potential for phytotoxic effects whereas immature compost may contain sufficient degradation intermediates which promote intensive biodegradation and competing with the plants roots for nutrients.

The phytotoxicity tests indicate that the composts obtained using the demonstration composter that has been designed for this project are phytothreptic. Thus indicating that there are no phytotoxic compounds that can inhibit seed germination or damage plant growth. The germination index (GI) varied from 107% to 157% with the control index being 100%. From the analysis of soil characteristics, where cultivations took place, it is shown that the organic content is very low 1.65% and there is a need for enrichment using compost.

The open field experiments that have been carried out for selected cultivation enable to evaluate the agronomic value of compost and to implement an impact assessment of compost on the physicochemical characteristics of the soil as well as on the growth and the development of

cultivations in a real environment. The selected seeds for agricultural applications included sugar beet, wheat and maize since these are the primary cultivations that are being practiced in Doukkala region covering approximately 75% of the irrigated perimeter. Variable doses of compost mixture were used for the cultivations. For sugar beets the highest compost dose gave the highest biomass yield while in the initial stage of cultivation no effect was observed with different compost doses. The use of compost affected the amount of biomass produced following an increasing series in comparison to cultivations where compost was not applied. In particular the amount of 2tn/ha gave 3.5% increase in biomass, the 5tn/ha gave 31.5% while the highest compost dose of 7tn/ha achieved the highest biomass increase of 52.3% on sugar beets.

For maize cultivations two different types of compost were used. The experimental results indicate that 32% and 42% more growth is achieved when compost was used. Also the growth is better when using compost, than using fertilizer, the increase in growth being 21.3% and 30.4% depending on the type of compost. Also, it was observed that lower compost quantities 5 T/ha give better results than higher quantities of 7.5 T/ha.

The soil used for cultivations was examined and the results show that there is a lack of organic matter and nutrients such as phosphorus, potassium and nitrogen. When compost was used, the soil properties were improved and the presence of heavy metals was very low.

1 Introduction

In countries with semi arid climates, such as Morocco, the humidity and temperature conditions favour soil mineralization and particularly in the irrigated areas. Consequently, the absence of organic additives and/or the use of cultivation residues, entail in the long term, the reduction of the amount of organic matter in the soils. This could be accompanied by a degradation of the structure of the soil and of a deterioration of the chemical fertility; thus affecting the durability of the production systems.

The irrigated perimeter of Doukkala region, in Morocco, which is characterized by intensive cultivations that take place in years of normal rainfall, is not excluded from the problem of soil mineralization mentioned above. The removal of plant residues from the cultivated areas for the supply of livestock in conjunction to the a low use of manure[1] have enormously contributed towards the degradation of the soil with respect to their organic matter content despite the efforts that have been made to stimulate the interest of farmers on the importance of organic additives to the soil.

[1] since manure are generally used in market gardening cultivations tomatoes, potatoes etc

In other areas in Morocco, wastewater and solid waste, containing an important percentage of organic matter, pose serious environmental and public health problems. In particular sludge originating from WWTP can be a significant source of a lot of undesirable substances in the soil and plants. Heavy metals and complex organic compounds are among the most persistant pollutants present in sewage sludge. However, sludge generated from WWTP and other biodegradable organic waste, constitute a potential source of organic matter for the soil when used properly. This potential renders the necessity of a special treatment of sludge and other BOW in order to be used for the enrichment of the soil and/or the improvement of agricultural production. Composting is a generally accepted and highly beneficial method for sewage sludge and other BOW treatment-stabilization since it results in the reduction of the contents of a lot of pollutants and positively influences other physical and chemical properties of that waste. Thus composts can provide a rich organic nutrient source and soil conditioner for agricultural and horticultural applications. Nevertheless composts must be tested prior to their use for potential phytotoxic compounds which may inhibit and damage plant growth or even endanger public health.

2 Methodology

This section describes the methodology followed for the implementation of the laboratory phytotoxicity tests and the open field experiments for the characterization and evaluation of the produced composts.

2.1 Methodology on laboratory phytotoxicity tests

The phytotoxicity experiments were carried out on filter paper in Petri dishes. Ten millilitre of the corresponding aqueous extract (1/10, w/v) from the composts were introduced into dishes, with distilled water used as control in other dishes. Twenty seeds of lettuce seeds (Lactuca sativa) were then placed on the filter paper and the dishes placed in a germination chamber maintained at 25°C in darkness. The germination percentages with respect to the control and root lengths were determined after 5 days. The germination index (GI) was calculated according to the formula given below.

$$RSG(\%) = \frac{number\ of\ seeds\ germinated\ in\ compost\ extract}{number\ of\ seeds\ germinated\ in\ control} \times 100$$

$$RRG(\%) = \frac{mean\ root\ lenght\ in\ compost\ extract}{mean\ root\ lenght\ in\ control} \times 100$$

$$GI(\%) = \frac{RSG \times RRG}{100}$$

Three repetitions have been performed, for each compost, by selecting three separate samples of each compost and testing it according to the aforementioned procedure while two control tests were also performed using distilled water for comparison reasons. The results obtained, for each compost, are given in the results and discussion section.

2.2 Methodology on open field experiments

The open field experiments for the seed cultivation of sugar beet, wheat and maize were performed in the SEMVA in Zemamra region. The compost tested was a mixture of compost 2 and 3, in equal proportions, resulting from the operation of the 2^{nd} and 3^{rd} trial of the in-vessel bioreactor and compost no 4, as presented in Deliverable 13.

For sugar beets cultivations, the mixed compost was spread on the soil according to the experimental protocol that follows. The cultivation testing involved the application of the mixed compost in three different doses while a control test was also performed for comparison reasons. The doses of compost that was applied are presented in Table 2. The tested doses were: 0 T/ha (control), 2.5 T/ha, 5 T/ha and 7.5 T/ha.

Table 1: Doses of compost applied for the open field cultivations

Test	Dose [T/ha]	Dose per elementary parcel [kg]
T1 (Control)	0	0
T2	2.5	7.5
T3	5	15
T4	7.5	22.5

The experimental protocol used for sugar beets cultivations is shown in Table 2.. The total area of each test is about 480m^2 with each elementary parcel covering an area of 30m^2 (5m x 6m).

Table 2: Experimental protocol followed for the open field cultivations of sugar beets

Block 4	Block 3	Block 2	Block 1
T3	T1	T4	T1
T2	T3	T2	T4
T4	T2	T1	T3
T1	T4	T3	T2

Soil samples were taken before and after sowing for the physicochemical characterization of the soil.

The agricultural works carried out in the field for the technical control of the experimental cultivations of sugar beets were as follows:

- Soil preparation for planting using the plough to cut furrows in and turn up the soil
- Sowing was performed on in seed holes spaced at 20cm in lines 50cm apart.
- The sugar beet variety planted is a multi-germ “Olga”
- Apart from the recorded rainfalls (Table 5), the cultivations were irrigated three times using a total water quantity of 900m3/ha.
- Treatments on the cultivation have been performed against wild grass and diseases

The cultivations of maize started on the 15 of April 2008 which was the seeding date and lasted until the 1st of July 2008, total of 77 days. Two different types of compost were used, compost (2 + 3) in a mixture in equal proportions and compost no 4.

The cultivations protocol for the two different composts is shown in Table 3. The field is divided into five elementary parcels (T_1 – T_5) with dimensions of 6m x 5m and an area of $30m^2$ each.

Various blocks were formed (B_1 – B_4) in order to include five elementary parcels each. The various combinations of the elementary parcels form 4 different blocks. The reason for this setup is to eliminate any influence on the growth of the cultivation that can be attributed to a certain position in the field study. So for both types of compost 20 elementary parcels were used.

Table 3 shows the addition of compost for each elementary parcel. The quantities used were T_1 = 0, T_2 = 7,5, T_3 = 15,0 and T_4 = 22,5 kg/parcel. For T_5 synthetic fertilizer was used 1,43 kg. The above figures correspond to 0, 2,5, 5,0, 7,5 T of compost per hectare and 0,477 T/ha fertilizer.

After the seeding, 32 days elapsed and measurements of the maize height were performed as well as on day 47, 61 and 77, in order to study the growth of the plants under the various conditions, that is, different compost type, different quantities of compost used. Height measurements took place for all plants in each elementary parcel and for all blocks.

Table 3. Protocol of maize cultivations using compost no 4 and no 5

A	Block 4	T5	T2	T1	T3	T4
	Block 3	T4	T1	T3	T2	T5
	Block 2	T3	T4	T1	T5	T2
	Block 1	T1	T2	T3	T4	T5
B	Block 4	T5	T2	T1	T3	T4
	Block 3	T4	T1	T3	T2	T5
	Block 2	T3	T4	T1	T5	T2
	Block 1	T1	T2	T3	T4	T5

3m

1m

5m

6m

A Compost (2+3) mix

B Compost 4

N° of the PE*	Kg/PE	Tons/hectare	
T1	0	0	
T2	7.5	2,5	Compost 4 or 5
T3	15.0	5	Compost
T4	22.5	7,5	Compost
T5	1.43	0,477	Fertilizer**

* : Elementary parcel

** : Fertilizer 456 g of NPK (18-46-0) and 975 g of KNO_3(Chemical fertilizer)

3 Results and discussion

In this section the obtained results from the laboratory phytotoxicity tests and the open field experiments are presented and discussed for the characterization and evaluation of the produced composts.

3.1 Results and discussion on the laboratory phytotoxicity tests

Based on the methodology presented in paragraph 2.1 four phytotoxicity tests have been performed one test for each composting end product. The characteristics of the composts used, four in total, are shown in Table 4.

Table 4: Physicochemical characteristics of composts produced

Parameter	Compost 1	Compost 2	Compost 3	Compost 4
Dry Solids (% d.s)	63.90	63.80	61.2	60.5
pH	7.31	7.28	7.03	7.3
Total Carbon (%)	28.84	33.84	23.80	31.29
Total Nitrogen (%)	2.86	2.85	2.43	5.12
C/N Ratio	10.08	11.87	9.79	6.11
NO_{3-} - N (mg/Kg d.w)	1286.48	998.43	388.12	3257.00
NH_{4+} - N(mg/Kg d.w)	302.62	207.73	38.65	304.10
Total P. as P_2O_5 (% d.s)	0.7584	0.9264	0.79322	4.22515
K. as K_2O (% d.s)	3.0118	3.9505	3.21070	0.53814
Ca (% d.s)	4.7107	5.4785	5.74819	4.71073
Mg (% d.s)	2.1266	2.0931	2.02320	0.93060
Cd (mg/Kg d.s)	0.4739	0.59735	0.72949	0.54460
Cr (mg/Kg d.s)	8.1537	11.19308	13.51757	13.00632
Cu (mg/Kg d.s)	64.2264	54.17476	82.47363	110.93610
Ni (mg/Kg d.s)	10.8509	11.96504	17.38393	10.05946
Pb (mg/Kg d.s)	34.0357	20.03207	38.15530	25.83016
Zn (mg/Kg d.s)	132.8445	109.24231	118.22976	730.18767

Figure 1 presents the phytotoxity test results of the compost produced in the first trial. The Figure is devided into four areas. The first area aquiring gemination index values from 0 to 25 represents the most phytotoxic values, the second area from 26 to 65 represents the phytotoxic values, the third area from 66 to 100 represents the non phytotoxic values while the fourth and last area (>101) represents the phytothreptic values.

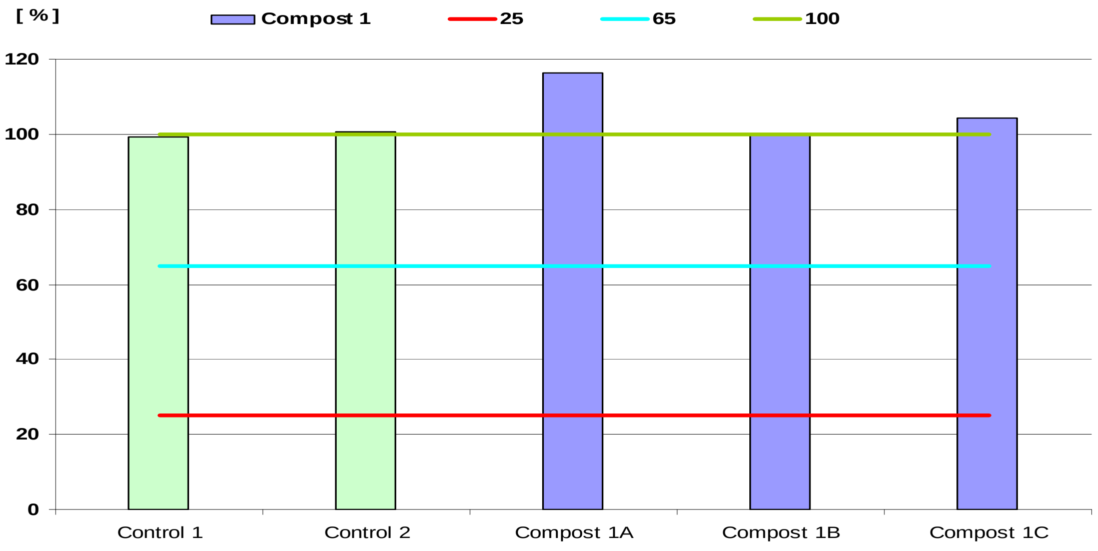

Figure 1: Germination index values of Lactuca sativa seeds using compost 1

According to Figure 1 the germination index values pointing the absence of phytotoxic substances for seed germination and plant growth acquiring. The samples tested had an verage GI value of 106.81% which is higher than the GI control value (100%) indicating that the decomposition of the organic matter during composting contributed to the disappearance of potential phytotoxic compounds.

Phytotoxicity is related to the solubility / extraction of metal, organic carbon and nitrogen. As far as there is a relationship between solubility, transportation of trace elements by organic soluble carbon and bioavailability, phytotoxicity can be considered an important factor in heavy metal plant uptake from composts. Figure 2 presents the phytotoxity test results of the 2nd compost. According to Figure 2 the 2nd compost appeared to be phytothreptic since it had stimulating influence on seed germination and root growth in all 3 samples that had been tested acquiring an average GI value of 123.5%. It was concluded that no phytotoxic substances for germination and growth were present and that compost is considered to be of high quality.

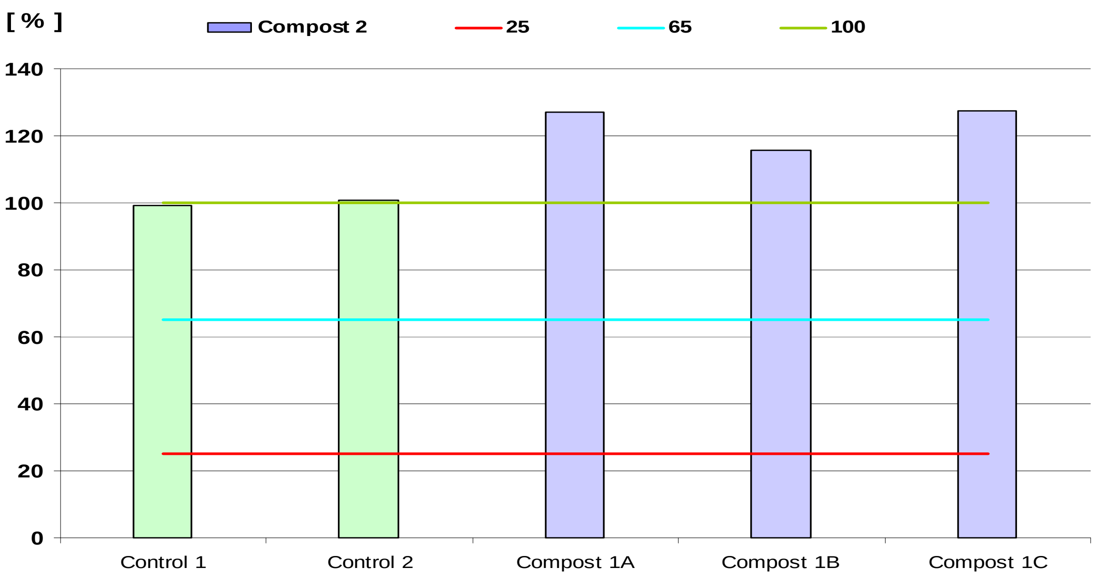

Figure 2: Germination index values of Lactuca sativa seeds using compost 2

As can be seen by the physicochemical characteristics of the 3rd compost in Table 3 the macro-element content was sufficiently high and at the same time the heavy metals concentration was within acceptable limits to promote seed germination and plant growth.

Figure 3 presents the phytotoxicity tests that had been performed in the laboratory to the 3rd compost.

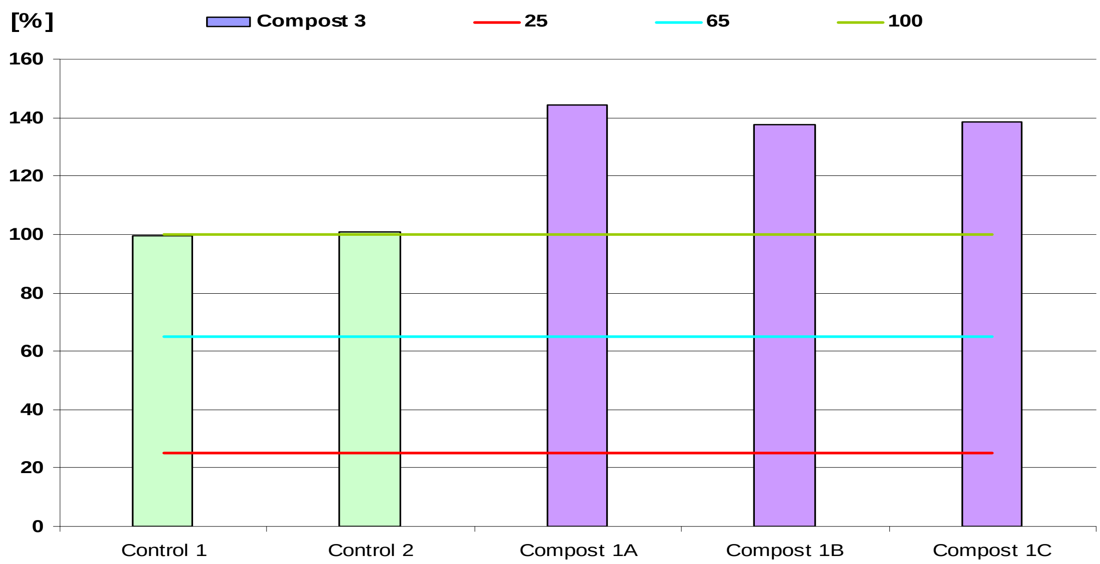

Figure 3: Germination index values of Lactuca sativa seeds using compost 3

According to Figure 3 the 3rd compost had stimulating effects on the tested seeds acquiring an average GI value of 140.1 and confirming the fact that the compost is phytothreptic and that phytotoxic compounds for germination and growth are not present thus classifying compost as of high quality.

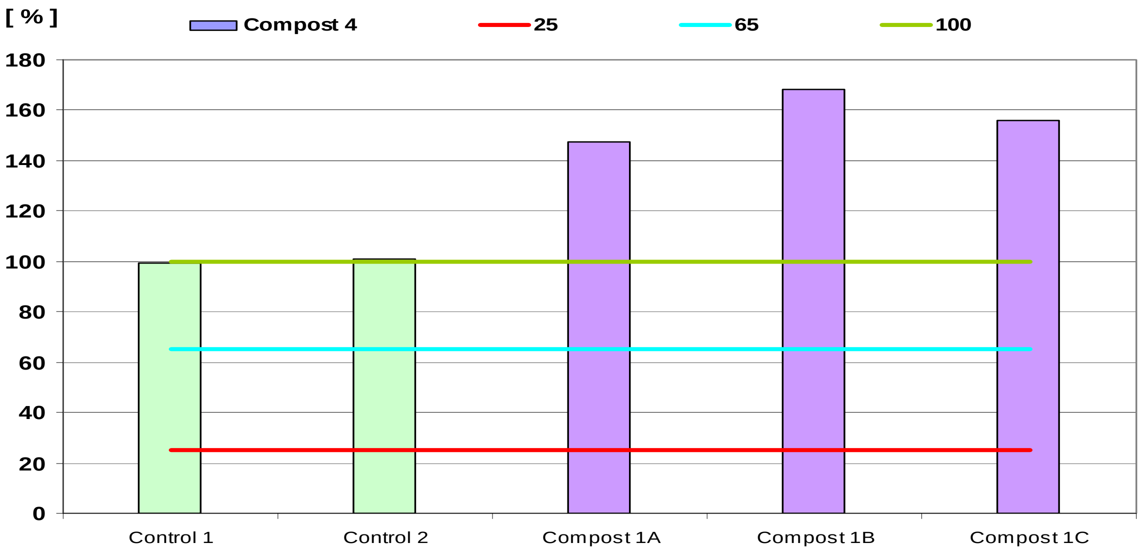

Figure 4: Germination index values of Lactuca sativa seeds using compost 4

According to Figure 4 all samples of the 4th compost presented significantly higher GI values with respect to the GI control values. In addition, the acquired average GI value of the 3 samples is 157.2% which is the highest value among all composting trials and this can be attributed to the increased nitrogen content incorporated to the end product as shown in Table 3.

3.2 Results and discussion on open field experimentation

3.2.1 Sugar beets cultivations

With respect to the open field experiments, as mentioned earlier, three species of seeds were selected for cultivations, namely maize, wheat, sugar beet roots.

The cultivation of wheat was abandoned due to plant illness while the maize plantation was ready in July 2008. The experimental programme on sugar beets and maize were successfully carried out. The results presented in this report include the cultivations of maize and sugar beets as well as soil parameters.

For sugar beet root plants several parameters were measured such as:

- The plant growth (height) on the 48th DAS
- The biomass acquired on the 48th DAS
- The biomass acquired on the 82nd DAS

Tests were carried out on soil and the initial physicochemical properties of the soil on which compost was applied are presented in Table 5.

Table 5: Soil Characteristics in Zemamra region where cultivations were performed

Parameters	**Value**
Aluminium oxide	35-37%
Mud	13,5-14%
Sand	49-50%
Organic Matter	1,65%
pH	7,85
Total Ca	0,09%
Electrical Conductivity	0,27mS/cm
Relative density	1,40-1,46
Available P_2O_5	10,5 mg/kg
Exchangeable K_2O	150,4 mg/kg

According to Table 5 the soil has an argillaceous-sandy texture, non calcareous, acquiring low organic matter, poor concentration of available phosphorous and moderately concentration of exchangeable forms of potassium. In regard to the climate conditions, Table 6 shows the monthly mean values of temperature, humidity, speed wind and precipitation that had been recorded throughout the duration of the experimental cultivations.

Table 6: Recorded climate conditions throughout the duration of the experimental cultivations

Month	Temperature (^{o}C)	Humidity (%)	Wind Speed (m/s)	Precipitation (mm)
Sept 2007	23,4	74,5	3,0	0
Oct 2007	21,8	71,2	2,6	29,2
Nov 2007	17,8	73,1	2,3	127,8
Dec 2007	14,6	78,8	2,2	38,7
Jan 2007	14,4	82,8	2,1	26,5
Feb 2007	17,0	76,8	1,8	20,4
Mar 2007	17,0	71,7	3,0	16,6
Total				259,1

These climate conditions are typical for Morocco with the exception of the precipitation level which presented a 20% reduction with respect to the average precipitation level of the last 42 agricultural seasons (320mm).

Examination of sugar beet growth on the 48th DAS

The height of sugar beets was measured on the 48th DAS when sugar beet leaves started to grow. Table 7 presents the data obtained according to which sugar beet growth did not present significant difference between the various doses of compost. Consequently, the doses applied in the open field did not have any significant effect on the germination nor on the growth of sugar beets at that time.

Table 7: Sugar beet growth [ft/ha] for the different compost applications on the 48th DAS

Compost Test	ft/ hectare	Variation
T1 (Control)	117000	17397
T2	130000	11547
T3	115000	19148
T4	123000	15491

Biomass examination of sugar beets

The biomass of sugar beets was measured in two different phases during the cultivation cycle. The first measurement took place on the 48th DAS when sugar beet leaves started to grow while the second measurement was carried out on the 82nd DAS at the beginning of crop formation. The evaluation of biomass was calculated from the average weight value of six plants from each elementary plot.

Biomass examination of sugar beets on the 48th day

The statistical analysis performed on the whole plant, the leaves, the roots and on the ratio of leaves over roots on the 48th DAS, when sugar beet leaves started to grow, did not show any significant differences between the different compost doses as shown Table 8. Thus the effect of compost contribution was not significant in the 48th DAS.

Table 8: Biomass of sugar beet cultivation acquired on the 48th DAS

Compost Test	**MFF g/plant**	**E-type**	**MFF g/plant**	**E-type**	**MFF g/plant**	**E-type**	**RFR**	**E-type**
T1 (Control)	25.14	10.34	23.10	9.60	2.03	0.94	12.05	3.05
T2 (2.5 T/ha compost addition)	20.34	8.96	18.77	8.22	1.57	0.74	12.15	1.01
T3 (5.0 T/ha compost addition)	21.23	1.31	19.48	1.05	1.75	0.29	11.30	1.42
T4 (7.5 T/ha compost addition)	19.56	8.30	17.92	7.59	1.64	0.73	11.07	1.25
Average Value	**21.56**	**7.53**	**19.81**	**6.91**	**1.75**	**0.67**	**11.64**	**1.73**

MFT : Average weight of the total mass of a plant (leaves and root)

MFF : Average weight of the leaves of a plant

MFR : Average weight of the root of a plant

RFR : Ratio of the average weight of leaves to the average weight of root

Biomass examination of sugar beets on the 82nd day

On the 82nd DAS, the average weight of the plants leaves and roots presented significant differences between the different compost doses as indicated in Tables 9 and 10. An increase of the net weight of the leaves and roots of the plants was observed as the applied compost doses increased. In particular for the case of the 7.5 T/ha of compost applied (T4), sugar beet leaves and sugar beet roots presented 57% and 38.4% average weight increase/augmentation respectively in comparison to the sugar beet leaves and roots that compost was not applied (T1) as shown in Table 9. The average weight of the whole plant (leaves and roots) shows a proportional increase in compost contribution in plant growth as in Table 10. The compost doses applied of 2.5T/ha, 5.0T/ha and 7.5T/ha presented an increase to the total plant growth of approximately 3.5%, 31.5% and 52.0% respectively. Whereas the ratio of the average weight of leaves over that of the root also increased by of 6,5%, 13,7% and 16% for compost doses of 2,5T/ha, 5T/ha and 7,5T/ha respectively. Figure 5 illustrates several photos of the agricultural site where sugar beets seeds have been cultivated.

According to the obtained results on sugar beet cultivations it can be concluded that the produced compost from the in-vessel bioreactor had stimulating effects on plant growth.

Table 9: Biomass of sugar beets leaves and roots acquired on the 82nd DAS

Compost Test	**MFF g/plant**	**%augmentation**	**MFR g/plant**	**%augmentation**
T1 (Control)	**205.00**	**-**	**76.25**	**-**
T2	**209.75**	**2.30**	**81.50**	**6.9**
T3	**273.50**	**33.41**	**96.25**	**26.2**
T4	**322.75**	**57.44**	**105.50**	**38.4**

DAS : Days after sowing

MFF : Average weight of the leaves of a plant

MFR : Average weight of the root of a plant

Table 10: Biomass of sugar beets total mass (leaves and roots) and the acquired on the 82nd DAS

Compost Test	**MFF g/plant**	**%augmentation**	**RFR**	**%augmentation**
T1 (Control)	281.25	-	2.63	-
T2	291.25	3.50	2.80	6.5
T3	369.75	31.5	2.99	13.7
T4	428.25	52.3	3.05	16.0

DAS : Days after sowing

MFT : Average weight of the total mass of a plant (leaves and roots)

RFR : Ratio of the average weight of leaves to the average weight of root


Betterave à sucre
Var. Olga
Bloc 1


composting
MOROCOMP
Betterave à sucre
Var. Olga
Bloc 1

Figure 5: Photos illustrating the implementation of sugar beets cultivation in Zemamra

3.2.2 Maize Cultivations

As mentioned earlier for the maize cultivations, two different composts were used. One compost was obtained from an equal mixture of the trials 2 and 3, compost no (2+3), while the other one was obtained from the 4th trial compost no 4. After seeding and on selected time intervals, the height of the maize was measured. More specifically, the dates chosen for the height measurement were 17/5/2008(32nd day) after seeding, 1/6/2008(47th day), 15/6/2008(61st day), 1/7/2008 (77th day). Tables 11a, 11b, 11c, 11d show all the results of the maize growth from the various blocks and elementary parcels. For comparative reasons the average growth of maize for each of the five elementary parcels is shown in Table 12 for compost no (2+3) and in Table 13 for compost no 4.

Table 11a. Height of maize plant (cm) 17/5/2008 (32nd day)

		Height of plant with addition of									
	Plant	Compost N° (2+3)				Fertilizer	Compost N° 4				Fertilizer
Block	number	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
	1	9	7	9	7	6	6	8	7	7	6
	2	8	6,5	6	6	7	8	6	7	5	8
	3	9	6	5	8	6,5	8	9	9	9	7
1	**Average**	**8**	**6,5**	**6,67**	**7**	**6,5**	**7,33**	**8,5**	**7,67**	**7**	**7**
	1	6	9	9	6	9	6	7	9	7	6
	2	5	6	7	8	6	8	8	9	9	8
	3	6	7,5	6	6	8	9	7,5	9	8	8
2	**Average**	**5,67**	**7,5**	**7,33**	**6,67**	**7,67**	**7,67**	**7,5**	**9**	**8**	**7,33**
	1	7	6	9	8	8	7	6	7	6,5	6,5
	2	6	7	7	7	6	6	7	6	6	7
	3	8	9	8	6	6	8	6	6	7	7
3	**Average**	**7**	**7,33**	**8**	**7**	**6,67**	**7**	**6,33**	**6,33**	**6,5**	**6,83**
	1	8	6	7	8	6	7	7	7	7	6
	2	7	7	5	6	7	6,5	6,5	9	6	6
	3	7,5	8	6	7	9	6	6	8	8	6
4	**Average**	**7,5**	**7**	**6**	**7**	**7,33**	**6,5**	**6,5**	**8**	**7**	**6**
Average		**7,04**	**7,08**	**7**	**6,92**	**7,04**	**7,13**	**7,21**	**7,75**	**7,13**	**6,78**

Table 11b. Height of maize plant (cm) 1/6/2008 (47nd day)

Block	Plant	Addition of Compost N° (2+3)				Fertilizer	Addition of Compost N° 4				Fertilizer
		T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
1	1	18,5	25	28	28	23	19	26	28	38	21
	2	23	17	30	20	25	17,5	23	27	33	19
	3	17	20	30	26	25	22	24	24	32	18
	Average	**19,5**	**20,67**	**29,33**	**24,67**	**24,33**	**19,5**	**24,33**	**26,33**	**34,33**	**19,33**
2	1	19	20	23	20	20	20	19	20	19	40
	2	26	19	23	17	19	19	17	19	20	41
	3	22	26	24	23	26	18	20	18	22	44
	Average	**22,33**	**21,67**	**23,33**	**20**	**21,67**	**19**	**18,67**	**19**	**20,33**	**41,67**
3	1	17	25	20	17	20	21	22	28	23	18
	2	19	21	22	20	18	22	23	27	20	19
	3	16	19	21	19	18	19	24	24	19	22
	Average	**17,33**	**21,67**	**21**	**19,5**	**18,67**	**20,67**	**23**	**26,33**	**20,67**	**19,67**
4	1	18	20	18	24	18	20	19	25	18	20
	2	18	21	19	21	18	17	20	26	20	19
	3	20	18	20	19,5	19	19	18	20,5	19	17
	Average	**18,67**	**19,67**	**19**	**21,5**	**18,33**	**18,67**	**19**	**23,83**	**19**	**18,67**
Average		**19,44**	**20,92**	**23,17**	**21,39**	**20,75**	**19,44**	**21,25**	**23,89**	**23,58**	**24,83**

Table 11c. Height of maize plant (cm) 15/6/2008 (61th day)

Block	Plant	Addition of Compost N° (2+3)				Fertilizer	Addition of Compost N° 4				Fertilizer
		T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
1	1	25	30	50	35	30	45	75	70	60	45
	2	32	40	50	35	40	39	66	65	60	37
	3	22	53	50	35	40	48	75	62	55	32
	Average	**26,33**	**41**	**50**	**35**	**36,67**	**44**	**72**	**65,67**	**60**	**38**
2	1	40	35	35	40	30	50	45	40	55	70
	2	40	35	48	30	48	50	45	40	55	70
	3	40	50	55	45	35	43	45	40	53	75
	Average	**40**	**40**	**46**	**38,33**	**37,67**	**47,67**	**45**	**40**	**54,33**	**71,67**
3	1	40	50	40	45	40	45	30	40	25	40
	2	40	50	50	45	40	45	30	37,5	40	45
	3	40	40	45	45	40	45	30	35	40	47
	Average	**40**	**40**	**45**	**45**	**40**	**45**	**30**	**37,5**	**35**	**44**
4	1	40	40	40	40	40	40	30	40	40	50
	2	40	40	40	48	40	40	40	40	55	57
	3	40	50	50	30	30	38	38	40	50	46,5
	Average	**40**	**43,33**	**43,33**	**39,33**	**36,67**	**39,33**	**36**	**40**	**48,33**	**51,17**
Average		**36,58**	**41,11**	**46,11**	**39,44**	**37,78**	**44**	**45,75**	**48,56**	**49,42**	**51,22**

Table 11d. Height of maize plant (cm) 1/7/2008 (77th day)

Block	Plant	Addition of Compost N° (2+3)				Fertilizer	Addition of Compost N° 4				Fertilizer
		T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
1	1	60	70	90	80	80	70	97	127	100	110
	2	70	70	110	70	83,5	90	63	127	100	92
	3	60	60	110	80	75	72	120	127	80	75
	Average	**63,33**	**66,67**	**103,33**	**76,67**	**79,5**	**77,33**	**93,33**	**127**	**93,33**	**92,33**
2	1	70	90	80	90	90	160	90	107	73	90
	2	80	60	70	80	85	100	86	90	77	80
	3	80	130	80	80	70	76	80	120	91	78
	Average	**76,67**	**93,33**	**76,67**	**83,33**	**81,67**	**88**	**85,33**	**105,67**	**80,33**	**82,67**
3	1	85	80	120	70	75	62	90	120	80	85
	2	80	120	100	75	80	70	100	110	60	90
	3	65	110	110	80	90	82	70	87	110	85
	Average	**76,67**	**103,33**	**110**	**75**	**81,67**	**71,33**	**86,67**	**105,67**	**83,33**	**86,67**
4	1	77	90	100	80	70	80	80	78	110	67
	2	60	90	100	75	80	57	70	85	110	70
	3	80	100	110	77,5	60	80	75	90	130	70
	Average	**72,33**	**93,33**	**103,33**	**77,5**	**75**	**72,33**	**75**	**84,33**	**116,67**	**69**
Average		**72,22**	**89,17**	**98,33**	**78,13**	**79,44**	**77,22**	**85**	**105,67**	**93,44**	**82,67**

The results indicate that on the 32nd day, after seeding, the growth ranged from 6,92 – 7,08 cm for compost no (2+3) and for compost no 4 the range was 6,58 – 7,75 cm, a slightly better growth than for compost no (2+3).

Within two weeks (47th day from seeding), the growth for compost no (2+3) ranged from 19,44 – 23,17 cm in height, while the cultivation with fertilizer gave values of growth of 20,75cm. Maize growth using compost no 4 ranged in height from 19,44 – 23,89cm.

On the 61st day the growth ranged from 36,58 – 46,11cm for compost no 4 and when fertilizer was used the growth was 37,78cm. For compost no 4, growth gave a range of 44 – 49,42cm and for fertilizer 51,22cm.

On the 77th day the growth for compost no (2+3) ranged from 72,22 – 98,33cm and for fertilizers 79,44cm. For compost no 4 the growth ranged from 77,22 – 105,67cm and for fertilizers 82,67cm.

Table 12. Average maize growth using compost no (2+3) and fertilizer

Dates	Days from seeding	Compost N° (2+3)				Fertilizer
		T1(0 T/ha)	T2 (2,5 T/ha)	T3 (5 T/ha)	T4 (7,5 T/ha)	T5
17/5/2008	**32**	**7,04**	**7,08**	**7**	**6,92**	**7,04**
1/6/2008	**47**	**19,44**	**20,92**	**23,17**	**21,39**	**20,75**
15/6/2008	**61**	**36,58**	**41,11**	**46,11**	**39,44**	**37,78**
1/7/2008	**77**	**72,22**	**89,17**	**98,33**	**78,33**	**79,44**

Table 13. Average maize growth using compost no 4 and fertilizer

Dates	Compost N° 4				Fertilizer
	T1(0 T/ha)	T2 (2,5 T/ha)	T3 (5 T/ha)	T4 (7,5 T/ha)	T5
17/5/2008	**7,13**	**7,21**	**7,75**	**7,13**	**6,58**
1/6/2008	**19,44**	**21,25**	**23,89**	**23,58**	**24,83**
15/6/2008	**44**	**45,75**	**48,56**	**49,42**	**51,22**
1/7/2008	**77,22**	**85**	**105,67**	**93,44**	**82,67**

Fig 6 shows the growth of maize when compost no (2+3) was used in various amounts. Initially, the amount of compost does not influence growth (32nd day), but as time increases, growth shows slight differentiation (47th day). More differentiation in growth is seen on the 61st day and much more on the 77th day. The three last measurements over time show that better growth is achieved when the quantity of compost used is 5 T/hectare. Less growth is observed when higher quantities of compost are used, that is, 7,5 T/ha, or even when fertilizer is used. So the optimum compost amount is 5 T/ha. Even the amount of 2,5 T/ha gives better results compared to the cultivations when fertilizer is used or 7,5 T/ha of compost.

Fig. 6. Growth of maize plant with different amounts of compost no (2+3)

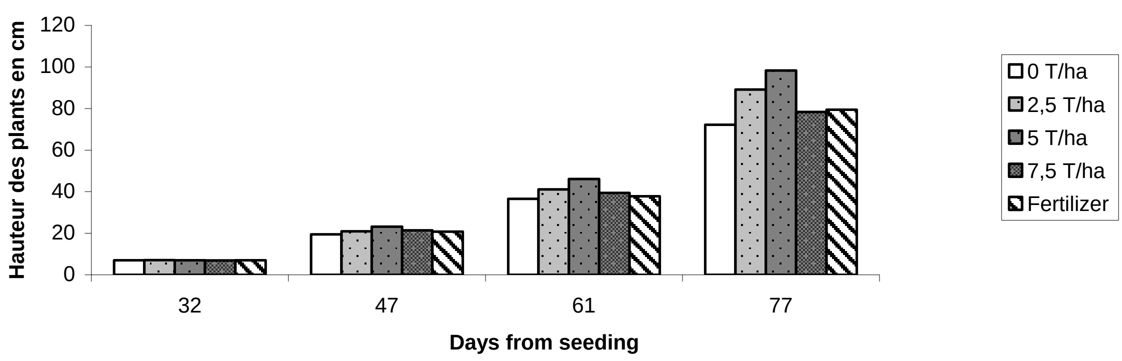

Fig. 7 shows the growth of maize when compost no 4 is used. On the 32nd day, the growth is similar for all different compost amounts and fertilizer. More increase is seen on the 47th day, growth is following an increasing series as the amount of compost increases and cultivations with fertilizer show the higher growth. On the 61st day, a similar pattern is followed as that seen on the 47th day. On the 77th day a completely different pattern is shown. The use of 7,5 T/ha and the use of fertilizer show lower growth compared with the compost use of 5 T/ha. In the case of compost no (2+3), the best growth is observed when 5 T/ha are used. The same behaviour can be seen for compost no 4.

Fig. 7. Growth of maize plant with different amounts of compost no 4

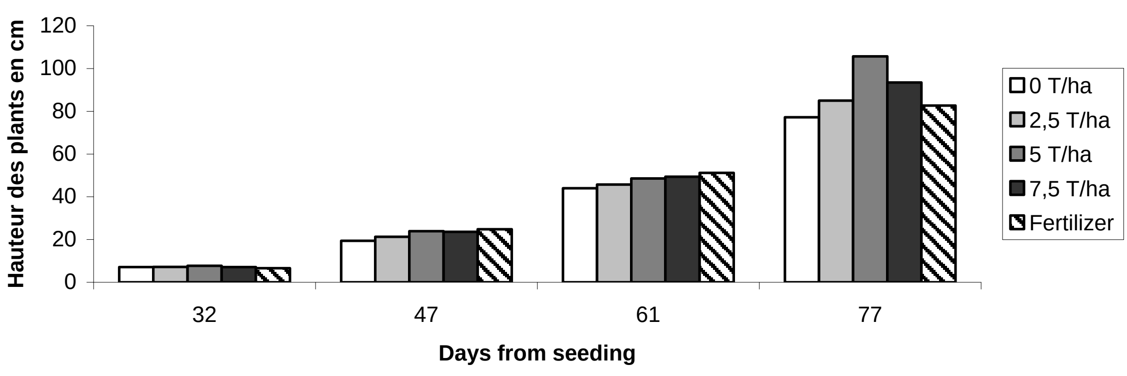

Fig. 8 and Table 14 present comparative results for maize growth using (a) zero compost, (b) 5 T/ha compost no (2+3), (c) 5 T/ha compost no 4 and (d) 0,477 T/ha fertilizer.

It is clearly shown that as time increases, growth increases for all different experimentations. However, the use of compost, 5 T/ha, gives much better results compared with the use of fertilizer. Also, compost no 4 shows slightly better performance than compost no (2+3).

Fig. 8. Effect of composts no (2+3) and no 4 and chemical fertlizer on maize growth

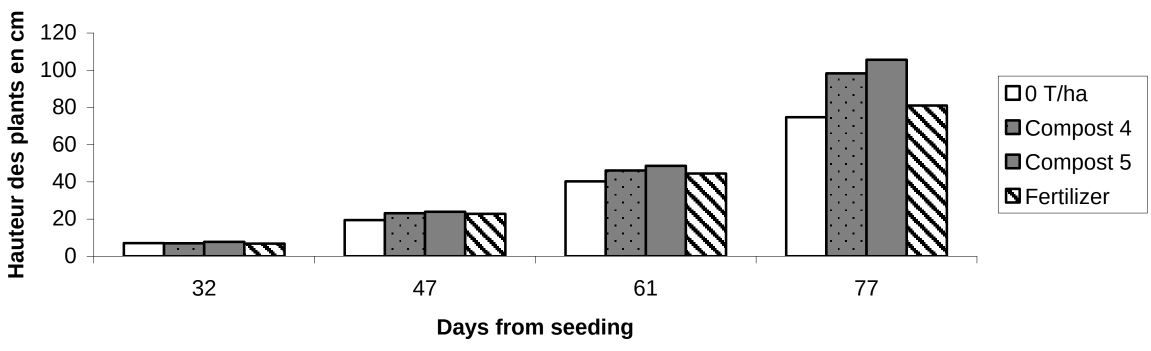

Table 14. Comparison of maize growth for compost no (2+3) and no 4 using 5 T/ha and 0,477 T/ha fertilizer				
Days from seeding	Compost 4	Compost 5	Fertilizer	0 T/ha
32	**7**	**7,75**	**6,81**	**7,08**
47	**23,17**	**23,89**	**22,79**	**19,44**
61	**46,11**	**48,56**	**44,45**	**40,29**
77	**98,33**	**105,67**	**81,06**	**74,72**

It is concluded that the cultivations of maize can give better results using compost 5 ton/ha, instead of using synthetic fertilizers. So these results should encourage the production of compost employing the composting process in a controlled environment, such as its production using the pilot system, designed for this particular project.

3.3 Soil Characteristics after Compost Application

As seen in Table 5 (section 3.2.1) the soil where compost was applied is quite poor in organic matter, it is very sandy and has a lack of nutrients, such as potassium and phosphorous, nitrogen. The application of compost has changed the soil characteristics but still more compost additions over the years will be required in order to enhance the soil and show substantial change in the long term. Table 15 shows the characteristics of the soil after compost application.

Table 15. Soil characteristics after compost application

Parameters	**Value**
Aluminium oxide	34,2-36,2%
Mud	13,2-13,8%
Sand	48-51%
Organic Matter	1,73%
pH	7,6
Total Ca	0,095%
Electrical Conductivity	0,29mS/cm
Relative density	1,36
Available P_2O_5	11 mg/kg
Exchangeable K_2O	220 mg/kg
Total Nitrogen	1.15 g/kg
Metals	Very low concentrations

It is seen that the organic matter has slightly increased as well as phosphorous, potassium and nitrogen, while heavy metals are low. The organic matter and the nutrients are the materials that assisted the growth of the cultivations. To improve the soil properties even more, compost will be required to be added gradually when cultivations take place.

4 Conclusions

The laboratory phytotoxicity tests indicate that the produced compost is phytothreptic for all the composting trials that have been performed during the 3rd Task of MOROCOMP project. This is an evidence that there is an absence of phytotoxic compounds that can inhibit seed germination or damage plant growth. In particular the compost resulted from the 4th trial acquired the highest germination index among all composts (157.2%) and this can be attributed to the high nitrogen content incorporated into the product.

In open field experiments variable doses of compost (mixture of equal composts proportions produced in the 2nd and 3rd trial) were used for the cultivations of sugar beets, and for maize compost obtained from trials (2+3) and 4. For sugar beets the results obtained on the 48th day after sowing showed that compost did not have negative effect on seed germination and on sugar beets growth. On the 82nd day after sowing it was confirmed that different doses of compost had positive effects on sugar beets growth. The stimulating effects of compost showed that the highest compost dose (7tn/ha) achieved the highest biomass increase on sugar beets of 52.3% in comparison to the sugar beets where no compost was applied and thus confirming the high fertility value of the produced compost. Also, the use of lower quantities of compost affected the amount of biomass produced following an increasing series. The amount of 2tn/ha gave 3.5% increase in biomass while the amount of 5tn/ha gave 31.5% increase showing an exponential growth in relation to the amount of compost used.

It is worth mentioning that the experimental analysis related to soil quality and characteristics indicate a very low organic matter as well as low nutrient concentrations, parameters that affect plant growth. The addition of compost has increased the organic matter of the soil as well as the presence of nutrients, phosphorous, potassium and nitrogen. Heavy metals are in very low concentrations. This was expected due to the fact that heavy metals are found in low concentration in the produced compost as shown in Task 3 (Deliverable 13). The available metal ions that can be taken by the plants are metals obtained through sequential extraction and this amount is very low. The gradual enrichment of the soil with compost will eventually assist the improvement of its fertility and hence the plant growth while heavy metals can remain in low concentrations.

The wheat cultivation was not successful due to an illness of the plants that was caused from external sources. The results from maize cultivations verify the beneficial effect of compost as fertilizer. As mentioned two different composts were used, no (2+3) and no 4. The cultivations lasted 77 days. In the initial stage, compost did not affect the growth but as time increases the cultivations are much affected by the presence of compost. For both composts, the cultivations using 5 T/ha show better results than the cultivations using 7,5 T/ha, or fertilizer. Comparing the two different types of compost it is shown that compost 4 shows a slightly better performance.