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High quality compost: a promising future for sustainable agro-industry in Morocco

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Abstract

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Intensive horticulture has developed substantially in Morocco over the last decades, with many associated benefits. However, it has also brought by a dramatic increase in the consumption of chemicals such as fertilizers and pesticides, including fumigants. Among these, methyl bromide, once widely used for the control of soilborne pests and diseases, is subjected to controls and phase-out under the Montreal Protocol due to its ozone-depleting potential. Final phase-out for developing countries like Morocco is due on January 1st, 2015.
As fewer chemicals are available to growers –other fumigants and pesticides besides MB are also subjected to regulatory restrictions, and importing markets are demanding produce grown with fewer chemicals – production within the high quality standards favoured by end consumers becomes a true challenge. With the aim of developing reliable, non-chemical soil pest management options, the United Nations Industrial Development Organization (UNIDO) has set up a composting pilot unit in Agadir in cooperation with APEFEL (Association of Fruit and Vegetable Growers and Exporters) and AGRINEWTECH. Composting processes, optimum compost production methods, as well as compost composition and quality parameters and application methods were evaluated, before promoting the technology among vegetable growers. This option has further provided an excellent solution to the large amounts of organic waste typically generated by horticulture, turning waste into a natural fertilizer that is rich in antagonists, and which has become a valuable input for enhancing the sustainability of the agro-industry sectors involved.

INTRODUCTION – METHYL BROMIDE PHASE-OUT IN MOROCCO

In 1992, when MB was listed as an Ozone Depleting Substance (ODS) under the Montreal Protocol, Morocco was already using about 440t of MB per year. Consumption increased dramatically in ensuing years, reaching a peak of 2700t in 2001 (Fig.1). For many years, this country was amongst the largest MB users in the developing world.

Sectors using MB were diverse, but mostly consisted of vegetables (tomatoes, peppers, cucurbits), bananas, strawberries and flowers. Various projects funded by the

Multilateral Fund (MLF) of the Montreal Protocol were undertaken to evaluate and demonstrate alternatives for the different crops and uses, and later to adopt the best suited and most feasible alternatives at the commercial level. Along this process, UNIDO has been the implementing agency of choice, and instrumental in achieving very successful MB phase-out: In 2012 consumption was reported at only 37t, and total phase-out is expected by end of 2013, one year ahead of the agreed deadline.

In the process, some sectors have adopted alternative chemical fumigants e.g. 1,3-Dichloropropene + chloropicrin and metham sodium (UNIDO, 2013b); Morocco has also become a leader in non-chemical options, notoriously grafting, which is now very widely adopted in tomatoes, peppers, cucurbits and other vegetables with excellent results, particularly when used as part of an Integrated Pest Management (IPM) programme (Besri, 2008). Soil-less production is also in place for some greenhouse crops and circumstances where this option works well. Addition of compost has been mostly geared at cucurbit, tomato and green bean production, in greenhouses and open fields (UNIDO, 2013b).

Overall, MB phase-out in Morocco has been an interactive process, where introduction of alternatives has occurred hand in hand with training and research. A Centre for Technology Transfer (CTT) was developed for this purpose through the projects in conjunction with APEFEL. The Centre is located in Agadir, where Moroccan intensive agriculture is concentrated (particularly vegetables). This paper describes the development of compost mixes with locally available organic matter sources in Morocco, and initial results in the use of compost as part of integrated soil pest management systems in intensive agriculture.

MANAGING SOIL HEALTH WITH THE AID OF COMPOST

Efficient control of soilborne pests and diseases is essential in intensive agriculture systems, where monoculture generally prevails and crop rotation is not always a feasible option. The need for high quality and health standards in the end product has traditionally led growers to resort to chemical soil fumigation, and in the case of Morocco mainly methyl bromide (MB). The need to phase-out this fumigant under the Montreal Protocol, together with requirements from distributors and market chains as well as restrictions imposed on other chemicals around the world, has encouraged the search for non-chemical options that may provide a longer term, more sustainable approach to soil pest management. Within this context, UNIDO in association with APEFEL have undertaken a project to find alternatives to MB.

Organic amendments such as composts, animal and green manures and by-products from agriculture, have been used in many countries to manage soilborne pests in different crops (Hadar, 2011; Noling, 2010; Oka, 2010). Although they cannot be considered a direct alternative to MB, organic amendments alter populations of soil microorganisms that can lead to decline of soil pathogen populations across time. This may thus be considered a long-term approach to reducing the need for soil fumigation, especially when used within an IPM approach (Hadar, 2011). Further, compost proves to be an excellent fertilizer, increases organic matter content in the soil, restores natural soil flora and enhances water retention capacity (Colla et al., 2012; Hadar, 2011).

There are however factors that may limit compost use, including inconsistency of results due to variable processing techniques which can lead to inconsistent quality of the compost (Griffin, 2012), the requirement to add large amounts of compost to the soil to produce an evident effect (Aydinsakir, 2009), and sometimes high transportation costs and the need to set up appropriate logistics at the farm. Further, the degree of efficacy of composts against soilborne pathogens may vary regionally, with soil types, pathogens to be controlled and cultivated crops (Griffin, 2012). Composting systems should thus be developed with specific needs in mind, tailored to particular circumstances as influenced by climate, soil types, crops produced, cropping systems and others. Further, continuous and thorough monitoring of compost characteristics and quality checks are essential to obtain the desired effect (Griffin, 2012); in fact, certification schemes are often needed to guarantee the best results. Finally, proper use of compost at the commercial level requires adequate training of end users.

COMPOST TRIALS AND INITIAL RESULTS

Composting process

A windrow or pile composting system with active air insufflation was selected for compost preparation in Morocco, which ensures adequate oxygen content and can speed up composting process. This system further allows to process large volumes of plant material at one given time. A composting platform was built, composed of four lanes, each one containing two lines 20m in length (Fig 3.) One line was reserved for repetitions, with four experimental units of 5m (linear) each.

Crop residues were shredded (particle size should be 5-20 cm), and together with the other ingredients (e.g. manure) were arranged in long piles approximately 2-4 m wide by 1.5–2 m high. Water was added and the mixture was periodically turned to ensure optimal aeration. It is important to maintain a C/N ratio =30, to keep moisture levels at 40-60% and ensure an oxygen level >10%.

In general terms, three main phases take place during the composting process: a) An active, thermophyllic phase in which rapid breakdown of composted materials is enacted by aerobic microorganisms; temperature rises above 45°C, sometimes higher. This phase may last from 1-8 months according to composting method used; b) A curing, mesophyllic stage, in which temperatures stabilize below 40°C, with a consequent shift in microorganism populations, and lasting less than 3 months and c) A maturation stage determined by the concentration of organic substances resistant to microbial degradation (humification) (UNIDO, 2013a).

When environmental conditions are adequate, microorganisms break up the material more easily and aerobic bacteria induce the emission of heat, carbon dioxide (CO_2) and ammonium, which in turn breaks into nitrites and nitrates. Since the degree of organic matter decomposition is closely connected to the suppression of diseases, compost should only be applied when mature, usually black or dark brown in colour, and with an earthy smell (UNIDO, 2013). Immature compost can be phytotoxic to plants due to high levels of ammonium, so storing before use is often recommended.

A fully equipped laboratory was also established through the UNIDO project at the CTT, with capacity to measure the different parameters determinant of compost quality including basic indicators such as pH, EC and humidity, but also biological oxygen demand (BOD), phytotoxicity and maturity tests. The lab is also equipped to perform microorganism counts and microorganism cultures, and for rearing biocontrol agents such as *Trichoderma* spp. In addition, full chemical analyses can be performed, including total carbon, nitrates and ammonium, phosphates, total sulphur and others. This has been of great help in determining the optimum composting process and end product.

Comparison of compost mixtures and quality check

Different kinds of available plant waste were evaluated, including tomato, pepper, watermelon, melon, green beans, citrus and ground olives. These were then combined with sheep manure (also locally abundant) and straw, with the aim of establishing appropriate mixtures that allow for a C/N = 30. Aside from O_2 concentration, other relevant factors measured included temperature, relative humidity, pH, CO_2 and NH_3 (used to estimate maturity of the compost), as well as EC (UNIDO, 2013b).

During the 2012/2013 season ten different compost mixtures and three mixtures with different C/N were studied (Table 1); an additional study was conducted to evaluate the quality of composts with four different C/N ratios: 25, 30, 35 and 40, made of different mixtures of plant and organic matter.

At the end of the composting cycle, quality checks were conducted (chemical and biological), in order to appraise the maturity of the compost produced. These checks were then compared to commercial composts subjected to international quality standards (Table 2). Chemical analyses of three composts produced at the CTT revealed very clear differences with commercial composts in terms of their organic matter and mineral element content. Compost No. 4 showed the best qualities as per international standards followed by Compost No. 3 (Table 2). It was clearly evident that compost contributes important amounts of mineral elements and can thus be used as a fertilizer. Biological analyses were negative in all composts with respect to total coliforms, thermo-tolerant coliforms, salmonellas, *Escherichia coli* and *Enterocoques* (UNIDO, 2013b).

Field trials

The best composts (Nos. 2 and 3, Table 1), as determined by analyses described above were selected for field trials performed directly on the premises of participating growers to test for their commercial suitability. Compost was incorporated on experimental plots, which was then solarized for four weeks before planting. Two different experiments were conducted, one with grafted tomato plants grown under a greenhouse, and another with zucchini plants grown in open fields. Compost was applied in three different dosages: 4, 7 and 14 kg (compost)/plant. For greenhouse tomatoes, var. 'Calvi' grafted onto a 'Beaufort' rootstock receiving the lower amount of compost – 4kg/plant - showed the highest yields (Fig. 2). Higher amounts appear to have reduced yields and may indicate that compost was incorporated in excessive quantities. Further trials are envisioned, solarizing in advance of compost application. Establishing optimum compost quantities and fully evaluating the effect of compost on soilborne pathogens, particularly nematodes, which can cause severe losses to tomato crops in Morocco are also needed.

Additional trials were conducted using five different kinds of composts and with potting substrates for green bean seedling production in four different dosages (20%, 40%, 60%, 80%). Results were measured in terms of the germination index obtained. Pots with 20% compost content produced the best results (95% germination index); a commercial compost produced best results and may be used as a reference for Moroccan composts prepared on site. Plant fresh weight and root system development were also recorded and analysed, showing once again significant differences between compost mixtures as well as with the control treatment (plain soil). Initial results indicate a disease suppression effect from the compost (UNIDO, 2013b).

Discussion

Initial results indicate that compost – whether incorporated into the soil or used as an amendment of potting substrate – brings clear benefits to crop production including soils with an enhanced organic matter content, promotion of beneficial organisms that help suppress soilborne pathogens and significant proportions of mineral elements which contribute to plant nutrition. Benefits are translated into higher crop yields and quality. In particular, the integration of compost with solarization and grafting has been shown to effectively control soil-borne pathogens. Further trials are however needed to confirm the ideal quantities of high quality compost that should be applied at the pre-plant stage and after a solarization period for different crops, in order to ensure the full antagonistic effect of the compost. This will allow for introducing the compost component in the commercial production process more efficiently.

With training and technical assistance, growers can incorporate compost as part of their Integrated Pest Management strategies, leading to a sustainable, longer-term approach to pest and disease management, not relying predominantly on chemical options. Careful quality monitoring and follow-up of processes plus continuous analyses of factors influencing compost quality are essential to the success of compost as a suppressant of soilborne diseases, fertilizer and soil enhancer.

THE WAY FORWARD – TECHNOLOGY TRANSFER

The Ministry of Agriculture of Morocco, in conjunction with UNIDO, has directly involved key stakeholders throughout the MB phase-out process. These include private sector institutions such as APEFEL, as well as individual growers, geared for different markets (domestic and export). At CTT growers are able to observe pest management strategies at work and get hands-on experience on their use. The center promotes new non-chemical control options and has been instrumental in determining the best compost production processes suited to Moroccan conditions and cropping methods. A composting pilot unit, where the composting process can be monitored in real-time, and a laboratory equipped to test and optimize the quality of the compost is available.

Since success with any composting system requires skills and experience, UNIDO and APEFEL have trained a team in composting technology, techniques and process monitoring. Training includes the selection of materials and their process, traceability of the final product, and quality control including compost maturity and pathogen suppression characteristics. This model is a clear example of efficient technology transfer and is leading the way for similar developments in other countries. The center has hosted a number of training events for participants from both Morocco and elsewhere; it has also prepared a number of technical and promotional materials including manuals and tool kits to assist growers interested in using compost. All this is attracting donors, mostly from the private sector and banks, who are interested in supporting its continuity, particularly in relation to the composting technology and business opportunities that may arise in relation to it.

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Figures

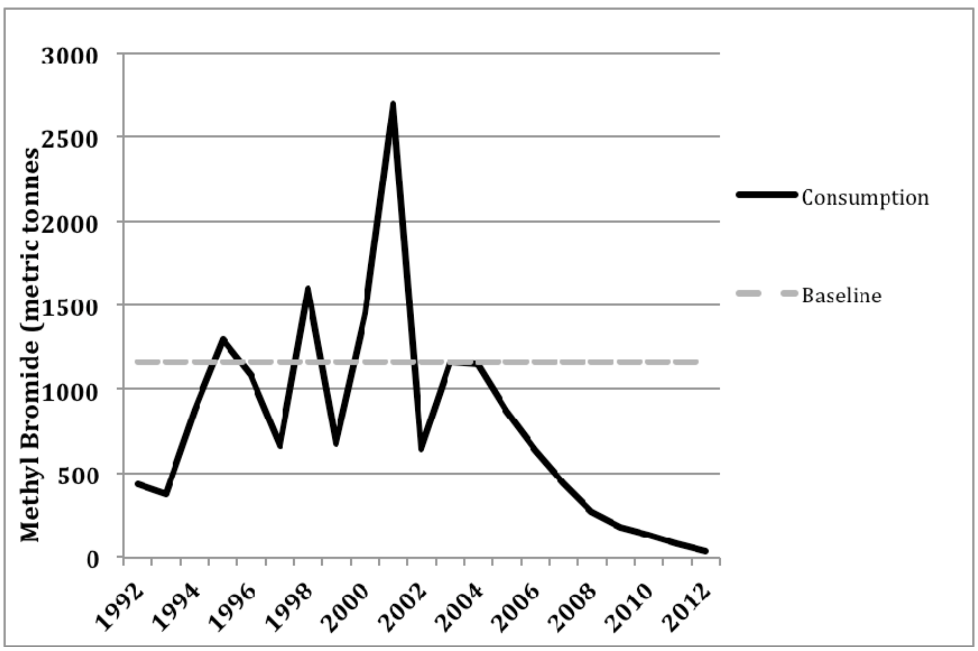

Fig. 1. MB consumption (controlled uses) in Morocco 1992 – 2012. (Source: Ozone Secretariat database, 2013)

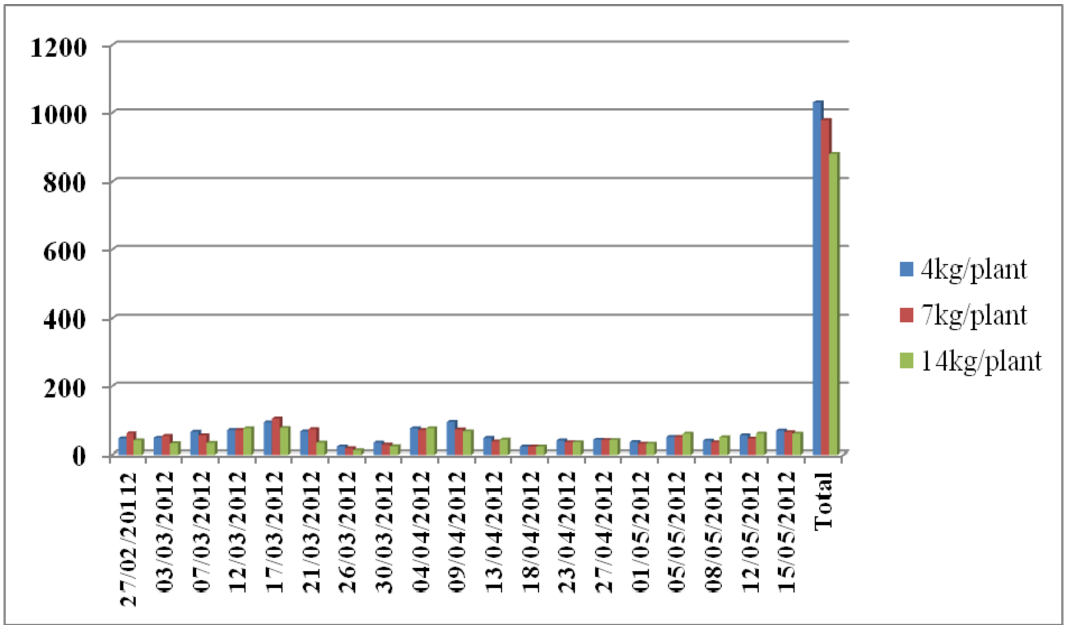

Fig. 2. Comparative yields obtained in a greenhouse tomato crop when applying different quantities of compost (UNIDO, 2013b)

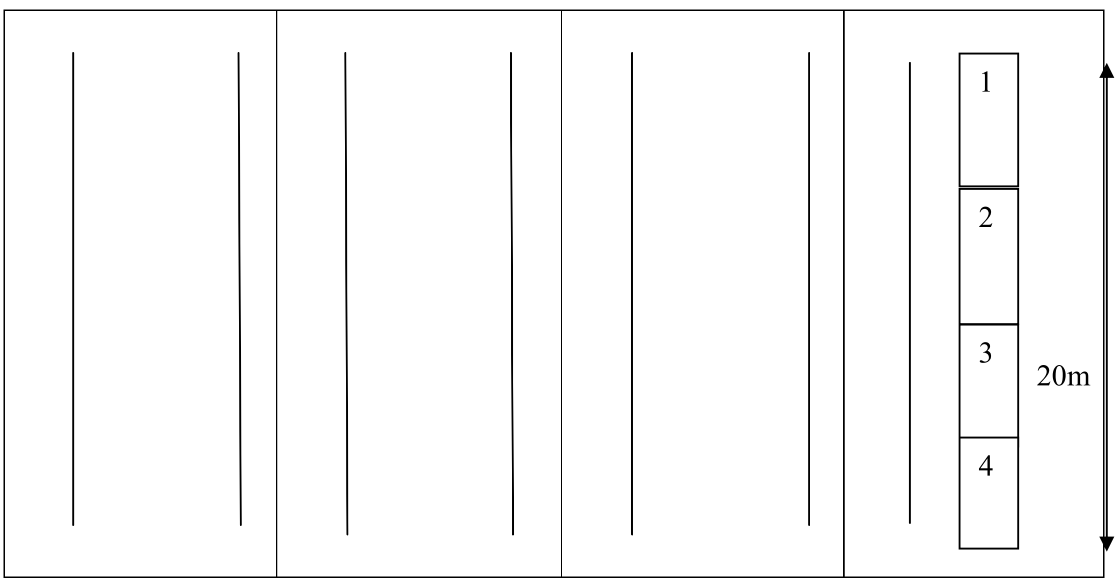

Fig 3. Layout of composting platform and trials at the Centre for Technology Transfer

Tables

Table 1. Composition of compost mixtures evaluated during the trials

Mixture	Composition
1	Fresh, ground tomato leaves (21m^3) + dried, ground tomato leaves (11m^3) + ground tree leaves (12 m^3) + ground weeds (dog's tooth, 11m^3)
2	Fresh, ground tomato leaves (12m^3) + dried, ground tomato leaves (15m^3) + sheep manure (8m^3)
3	Ground tomato leaves (24m^3) + sheep compost manure (6m^3) + sheep manure (9 m^3)
4	Ground tomato leaves (41.5t) + olive residue (27t) + sheep manure (40t)
5	Ground tomato leaves (14.2t) + green beans (2.1t) + citrus wood clippings (1.52t)
6	Ground tomato leaves (13t) + green landscape clippings (2t) + citrus wood clippings (1.4t)
7	Ground tomatoes (10.3t) + straw (0.4t)
8	Pepper (0.98t) + tomato (16.04t) + ground olives (5t)
9	Melon (2.1t) + tomato (10t) + ground olives (5t)
10	Melon (3t) + sheep manure (6t) + ground olive (6t)
11	Three composts (COV3, COV4 and COV5) made of tomato + sheep manure but with different C/N (25, 30 and 35 respectively)

Table 2. Chemical analyses of different composts

Parameters	**C Fv**	**C sp1**	**C AE**	**C AOQ**	**C BCT**	**C BF**	**C OV3**	**C OV4**	**C OV5**
pH	7.8	7,9	7,6	7,5	7,6	8,1	8	7,8	7,8
EC Mmhos/cm, 25◦C	2,16	4,7	1,55	1,43	4,86	4,98	13,6	13,4	24,5
Humidity %	8,57	2,53	4,76	5,9	5,25	5,86	2,53	2,33	14,51
Density g/cc	1,32	1,52	1,62	1,2	1,35	1,03	0,31	0,54	0,43
Org. matter %	3,52	7,08	6,74	6,74	5,58	19,12	51,78	37,22	35,5
Total sulfur %	0,07	0,04	0,07	0,56	0,21	0,98	1,19	1,05	1,33
Phosphorus mg	0,02	0,05	0,01	0,01	0,03	0,26	0,34	0,32	0,34
Potassium mg	0,17	0,54	0,11	0,12	0,34	1,09	3,2	2,93	4,13
Sodium mg	0,05	0,25	0,07	0,05	0,05	0,33	0,97	0,5	0.52
Calcium mg	3,54	4,77	2,92	4,15	3,69	2,85	5,11	6,22	8,44
Magnesium mg	0,7	0,34	0,4	1	0,61	0,72	0,39	0,38	0,46
Iron mg	15,4	0	176,9	15,4	15,4	0	35,7	57,1	14,3
Manganese mg	41,2	41,2	70,6	41,2	88,2	88,2	314,8	482,8	551,7
Zinc mg	17,7	17,7	2,5	17,7	22,8	53,2	84,9	104,1	147,9
Copper mg	24	0	0	24	16	8	0	0	0

CFV = Commercial compost compliant of Italian standards
C Sp1 = Commercial compost 1. CAE= Commercial compost 2. C AOQ = Commercial organic compost 3. CBCT= Commercial bio- compost 4.
C BF = Commercial compost 5. C OV3 = Tomato compost + sheep manure.
COV4 and COV5 as per Table 1 above.