Field Composting

Guidelines for pistachio producers

Maria K. Doula

Athens, 2016

Content

Preface

This guide was developed in the framework of the LIFE ENV/GR/951 project, entitled "Sustainable strategies for the improvement of seriously degraded agricultural areas: the example of Pistachia vera L." (AgroStrat) and aims to provide useful information and instructions to pistachio producers and farmers from the Mediterranean region regarding composting in field of the solid wastes generating after dehulling of pistachio nuts, as well as to present the composting method developed during the project.

One of the main objectives of the AgroStrat project was to recycle the solid waste produced from pistachio nuts processing. Therefore, a composting technique was developed using pistachio wastes, manure, straw and the natural zeolite, clinoptilolite. Clinoptilolite was added to the compostable mixture in order to adsorb the excess salts concentration and at the same time to contribute to the overall quality of the final product. This was the first time that a natural zeolite was used as feedstock component to this composting process, aiming to facilitate the production of an improved compost, which apart of the known properties will also act as "slow-release" fertilizer, due to the well-known properties of clinoptilolite to adsorb and keep essential nutrients in its framework and release them upon plant demand.

The potential harmful organic substances of pistachio wastes, and mainly polyphenols, were degraded during the composting process, allowing the safe use of the obtained compost in agricultural fields.

Therefore, composting could be an interesting alternative in recycling this type of agricultural waste produced in Mediterranean areas, resulting in an organic fertilizer suitable to be applied at pistachio orchards and not only, saving fertilization costs and improving the poor and erosion-endangered Mediterranean soils.

Pistachio dehulling wastes

Worldwide, harvest of pistachio nuts normally begins in late August and may continue through late October.

The nuts after harvest are transported to the processing facility, where they are dehulled, and dried. The main waste stream is produced from this process, which apart from hulls contains also pistachios, shells and water. On average, $2m^3/h$ of water are required for 1 tn fresh nuts during dehulling, while almost 1tn of nuts can be processed within an hour. Considering that dehulling process and the generated waste amounts are depended on the type of dehulling machine, nuts characteristics, water availability and also farmers' habits and practices, an average of 35-50% of the fresh nuts' weight will be recharged as waste. Therefore, for each ton of fresh nuts approximately 350-500 kg of solid wastes are produced. By the completion of dehulling process the sludge is recharged.

Many farmers separate the liquid part of the sludge in simple tanks or by using simple separation constructions. The sludge remains for some days in these tanks, where the solid part precipitates.

> Pistachio wastes must not be disposed untreated on soil due to their high electrical conductivity and the high content in polyphenols, chlorides and other constituents

Then the liquid part is recharged in water bodies or on soil while the solid part, some times is composted, but mainly disposed on soil or on streams and in wells. Wastewater is dark colored, bad smelling, has high electrical conductivity and is rich in polyphenols and in inorganics.

Dehulling machine in Aegina Island, Greece

Pistachios are dehulled in various types of machines and immediately after hulling, are put in flotation tanks. These tanks separate nuts, which have less than about 50% nutmeats (immature nuts, insect damaged nuts, and blanks) from those that have greater amounts of nutmeat. Those nuts with less than 50% meat tend to float while the others sink. The floaters are removed and handled separately from the sinkers.

Wastewater and solid pistachio waste in evaporation pond.

Why to compost pistachio wastes

Use of composts on cultivated land enriches soil with organic matter and nutrients, which otherwise would have been lost. Therefore, compost application on the poor and eroded Mediterranean soils, will significantly improve their quality and fertility and will strengthen their resilience capacity against impacts of the climate change.

Some particularities of pistachio waste should be considered prior composting and application on land. The most important is the high electrical conductivity of the material and the high polyphenols content.

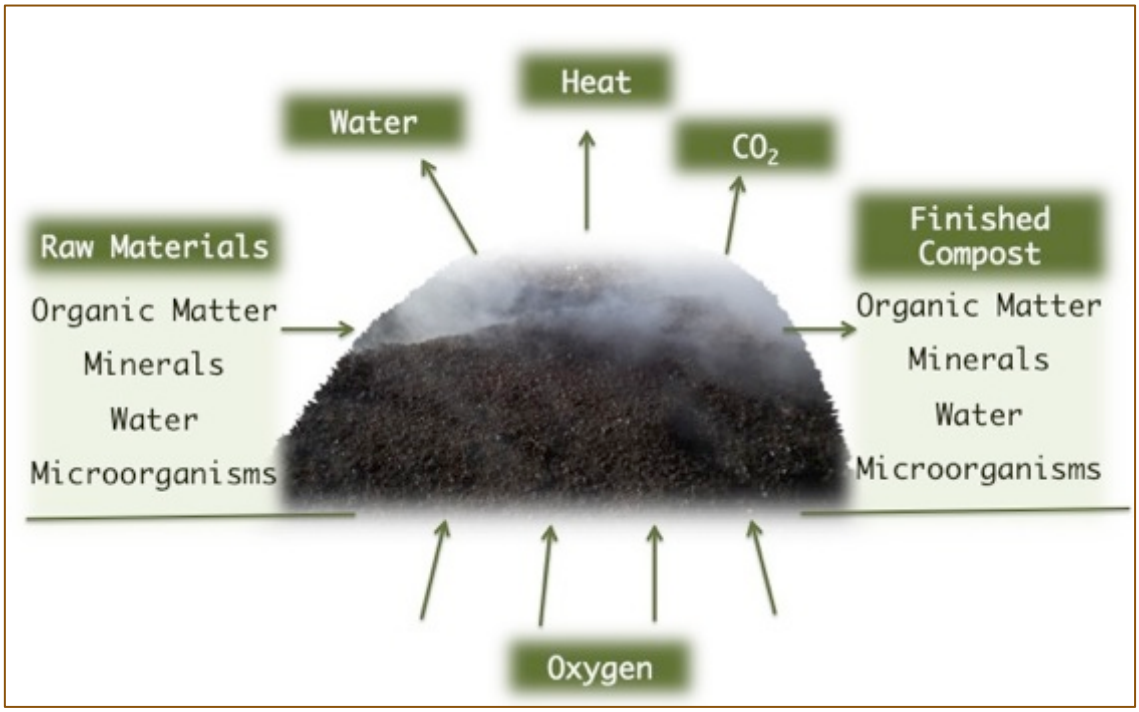
On the other hand, solid pistachio wastes are very rich in organic matter (up to 80%), potassium, magnesium, zinc, and, at lesser extent, phosphorus. By composting all these nutrients will return to soil and be exploited during the next cultivation period.

TABLE 1. Composition of solid pistachio waste and the respective thresholds for each parameter (Doula et al., 2015)

Parameter	Value in solid waste	Threshold according to literature
Organic matter, %	**79**	16-38 (field application)
Organic Carbon (C), %	**44**	> 19.4 (nursery application)
Total N, %	2.5	> 2
Moisture, %	**60**	40 - 50
pH	7.44	7.2 - 8.5
EC, mS/cm	**3.8**	< 4.0
Polyphenols, g/kg	**4.5**	In soil < 40 mg/kg
Total K, % (as K_2O)	**2.9**	0.5-1.8
Total P, % (as P_2O_5)	1.0	0.5-2.8
Total Ca, % (as CaO)	5.5	> 2.0
Total Mg, % (as MgO)	0.68	0.3-3
Total Na, %	0.69	< 2.0
Total Cu, mg/kg	106	70-600 (range within EU)
Total Fe, %	0.58	
Total Zn, mg/kg	99	210-4,000 (range within EU)
Total Mn, mg/kg	85	
Total B, %	0.13	
Cl^-, mg/kg (in mg/L)	4,900 (490)	< 500 mg/L (in water extract)[#]
NO_3^-, mg/kg (in mg/L)	1,200 (120)	< 1000 mg/L (in water extract)[#]
PO_4^{3-}, mg/kg	50	
SO_4^{2-}, mg/kg	354	
NH_4^+, mg/kg	308	< 300 FW (Switzerland limit)
NH_4^+, mg/L	31	Lower than 50 mg/L (in water extract)

Composting at field

Composting is an easy and environment friendly process, which is normally completed within 4-8 months under Mediterranean climatic conditions. However, despite being a simple process, producers should pay attention to ensure a minimum number of preconditions in order to produce high quality composts.



The composting process (Rynk, 1992)

Composting is a natural process of decomposing organic materials by using micro-organisms under controlled conditions.

During the composting process, micro-organisms consume oxygen while feeding on organic matter.
Active composting generates considerable heat,
large quantities of carbon dioxide, and water is released into the air.
This loss of carbon dioxide and water can amount to half of the weight of the initial materials.

Aerobic vs. Anaerobic Composting

Anaerobic Composting

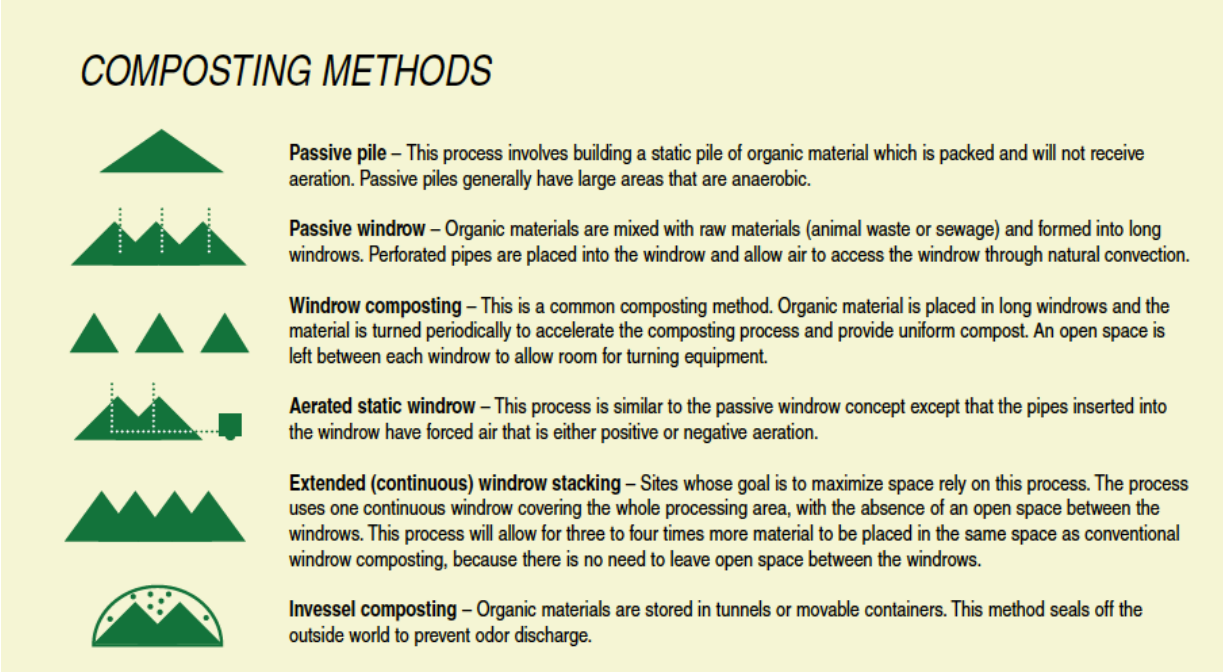
Almost any organic material can be processed in this manner. This includes biodegradable materials such as waste paper, grass clippings, leftover food, sewage and animal waste. This composting process enables organic matter to be broken down by bacteria in the absence of air. Anaerobic composting may be accomplished in large, well-packed stacks or other composting systems (silos, bags, digesters, etc.) where little oxygen can penetrate.

While anaerobic composting may be less labor-intensive because there is no need of turning the pile, it creates a strong odor, and takes longer to finish as the organisms do not have as high a metabolism.

Aerobic Composting

Aerobic composting is the process by which organic waste is converted into compost in the presence of air. During aerobic composting, the water content in the biodegradable material is removed. Aerobic composting reduces the waste into nearly one-half of its original volume and the process usually takes from two months to one year. The organic material is arranged to provide some insulation and temperatures during decomposition will rise to over 55-65°C.

If the temperature exceeds 65-70°C, however, the bacterial activity is decreased and stabilization slows. This process requires that the material be frequently turned in order to introduce oxygen to the material.



(Vermeer Corporation, 2008)

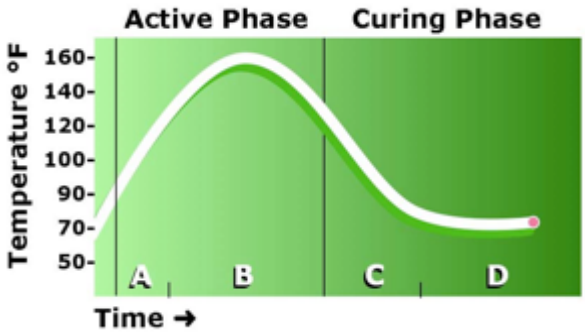
Windrow Composting

Windrow is the most commonly used composting method at field. The organic material is formed into long piles that are typically 1.5m-3m high (however, preferably lower than 2m), 3m-6m wide, and up to 100m or more in length, depending on available space and machinery for turning and wetting. This process requires an open space around the windrow or between them if more than one windrow, which provides room for the composting turning equipment to operate.

A windrow of pistachio wastes, manure and straw made in Aegina Island, Greece, in 2015

Composting stages

Composting occurs through the activity of microorganisms naturally found in soils. Under natural conditions, earthworms, nematodes and soil insects, such as mites, sowbugs, springtails, ants, and beetles do most of the initial mechanical breakdown of organic materials into smaller particles. Under controlled conditions, composters break down large particles through grinding or chopping.



Temperature changes in an average compost pile.
*A-mesophilic phase, B-thermophilic, C-mesophilic, D-maturation (*Rynk, 1992).

Composting phases

Formation of the pile or the windrow

Mixing the compostable material

Mesophilic phase (temperature range is 20-45 °C)

Mesophilic organisms multiply rapidly on the readily available sugars and amino acids, generating heat by their own metabolism and raising the temperature to a point where their own activities become suppressed

Thermophilic phase (temperature range is 50-70 °C or more)

Several thermophilic bacteria and a few thermophilic fungi continue the process, raising the temperature of the material to 65 °C or higher

Curing phase (temperature declines to ambient temperature)

Another group of thermophilic fungi starts to grow, bringing about a major phase of decomposition of plant cell-wall materials such as cellulose and hemi-cellulose. The temperature deceases gradually

Compost at the thermophilic phase

Temperature during the mesophilic phase should be maintained high to ensure no pathogens and weed seeds survival. Although there are not internationally established standards for temperature range during this phase, some countries have established their own standards (Böhm et al. 2000).

TABLE 2. Selected Temperature Standards during the mesophilic phase

Country	Compost Method	Temperature
Australia	All methods	>55° C for at least 3 days Allowance for variation and lower temperatures
Germany	Open Windrow	>55° C 2 weeks or >65° C for 1 week
Austria	All composts	>60° C for 6 days or >65° C for 3 days or >65° C for 2 x 3 days or
Switzerland		>55° C for 3 weeks or >60° C for 1 week or proven time temperature relationship
Denmark	All composts	>55° C for 2 weeks

Area selection

The area required for the composting site, storage for raw materials, and storage for the finished compost can occupy a considerable amount of land, and sometimes, building space and depends on the volume of material to be processed.

The compost materials can be placed directly on a compost pad (lime-stabilized soil or paved area), however a review of the area regulations should be performed to ensure that composting pad meets local and state requirements.

In choosing a site, several aspects should be considered

Management operations: access to roads and ease of handling materials.

Water quality protection: siting is the first step in preventing leaching and run-off into surface or ground water bodies.

Neighborhood relations: odor, noise, dust, debris and appearance of the operation.

Although windrow composting uses more land than other methods, it is recommended to compost in the field where the material is to be applied. Leaching of nitrates and other soluble nutrients is most likely to occur during curing phase and compost storage, therefore soils of intermediate permeability should be chosen, since highly permeable soils are most at risk. Ideally, the site should be several meters above the seasonally high water table, and several hundred meters away from wells or surface water. The slope of the site should be also considered, especially the potential for water to run into the compost piles during storms or snowmelt. Planting grass buffer strips

to slow run-off is therefore recommended. Providing roofs over some of the composting area or using covering composting textiles to divert precipitation and keep stored compost dry is also an effective practice.

The sites should be chosen considering of the distance from inhabited areas and the direction of prevailing winds during warm weather. Grinding and turning of the compost are better to be planned during the day since neighbors are less likely to be disturbed by the odors and noise.

Cold weather may slow the composting process by lowering the temperature of the composting material. The effects of rain and snow are potentially more serious. Heavy precipitation adds water to the composting mix and can impede or stop the composting process altogether. Excessive rain can also create a serious leachate (contaminated water) handling problem.

Site Characteristics

- Choose the location that has compacted soil or an impervious surface to reduce the seepage of the nutrient into the groundwater.
- The site must be sloped between 2 to 4%.
- The site must have a moderate to well drained soil surface.
- The site must be visible and have an easy access to hauling and storage.
- The site must have a permanent water diversion that works to keep surface runoff away from compost storage areas.
- Placement of waste storage, stacking or composting area should be at safe distance from floodways, wells or springs.

Odors management

Odors are the single biggest threat to a composting operation. Theoretically, aerobic composting does not generate odorous compounds as the anaerobic process does. Objectionable odors can come from certain raw materials or the process itself if composting is not properly managed.

There are three primary sources of odors at a composting facility (Cochran and Carney, 1996):

- odorous raw materials,
- ammonia lost from high nitrogen materials, e.g. manures, and
- anaerobic conditions within the windrow, which, however, can be minimized by proper management, e.g., use o a good mix of raw materials, avoid overly wet mixes, manage leachate and rainfall runoff management, monitoring temperature and turning for

materials regular aeration.

If the composting area is mismanaged, odors can be offensive and may generate complaints from nearby residents and passersby.

In most cases, the odors from a well-managed composting operation are periodic and short-lived

Waste handling and pre-treatment

Waste poses a threat to the environment and to human health if it is not managed properly and recovered or disposed of safely

There are safe ways of dealing with any waste, while any waste can be hazardous to human health or the environment if it is wrongly managed. Therefore, prior any action, the following issues should be defined/clarified (PEI, 1996):

- does the waste need a special container to prevent its escape or to protect it;
- what type of container suits it and what material can the container be made of;
- can it safely be mixed with any other waste or are there wastes with which it should not be mixed;
- can it safely be crushed and transferred from one vehicle to another;
- is it likely to change its physical state during storage or transport?

Composting pistachio wastes requires mixing with other types of wastes, such as manures, straw, food processing wastes or wastewater.

Special care should be taken to handle wastes safely for the humans, the animals and the environment

Waste must be kept safely against:

- corrosion or wear of waste containers;
- accidental spilling or leaking or inadvertent leaching from waste unprotected from rainfall;
- accident or weather breaking contained waste open and allowing it to escape;
- waste blowing away or falling while stored or transported;
- scavenging of waste by vandals, thieves, children, trespassers or animals.

Depending on the type and size of materials to be composted, it may be necessary to process theraw material using a tub or horizontal grinder. This process will standardize the particle size and help the decomposition process.

How to select feedstock materials and prepare the compostable mixture

Pistachio wastes are very rich in Organic Matter (up to 75-80%). On the other hand the Nitrogen content is up to 2.5-3.0%, providing a material with C/N ratio between 32 and 35,

which is considered favorable for composting. This means that the material could be composted without adding any other material. However, there are some reasons for which this process should not be left to occur naturally. Firstly, this would take long time to be accomplished, since the material is not rich in the required microorganisms. Secondly, the polyphenols content of the material is high, making it toxic for the microorganisms. However, by "diluting" pistachio wastes with other materials the polyphenols content is reduced, making the mixture more favorable for the microorganisms. Mixing with other materials must ensure that the optimal conditions for microorganisms are maintained.

If the proper amounts of food (carbon), nutrients, water and air are provided, aerobic organisms will dominate the compost pile and decompose the raw organic materials most efficiently

TABLE 3. Optimal conditions for rapid aerobic composting (Rynk, 1992)

Condition	Acceptable	Ideal
C:N ratios of combined feedstock	20:1 to 40:1	25-35:1
Moisture content	40-65%	45-60% by weight
Available oxygen concentration	>5%	>10% or more
Feedstock particle size	<2,5 cm	Variable
Bulk density	500-550k/m^3	500-550k/m^3
pH	5.5-9.0	6.5-8.0
Temperature	43-66°C	54-60°C

Many different materials can be found in fields and used as feedstock. The choice among them is depended on their availability, amount and chemical/physical characteristics.

AgroStrat proposes the following mixture for preparing a good compostable mixture

- **10 parts of pistachio wastes**
- **5 parts of manure**
- **1 part of straw (almost zero input of nitrogen)**
- **1 part of clinoptilolite (natural zeolite)**

How to calculate the C/N ratio of the mixture

C/N =

$$\frac{(parts\ of\ Pistachio\ waste\ x\ \%\ C) + (parts\ of\ manure\ x\ \%C) + (parts\ of\ straw\ x\ \%C)}{(parts\ of\ Pistachio\ waste\ x\ \%\ N) + (parts\ of\ manure\ x\ \%N)}$$

$$\frac{(10x44\%) + (5x70\%) + (1x98\%)}{(10x2\%) + (5x3\%)}$$

= 25

Addition of the natural zeolite, clinoptilolite, is recommended in case that pistachio wastes have very high salt content.

Preparation of the compostable mixture

The most important, when preparing the mixture, is to ensure that the feedstock materials are well mixed and the windrow or the pile is as uniform as possible, therefore, the following steps are recommended:

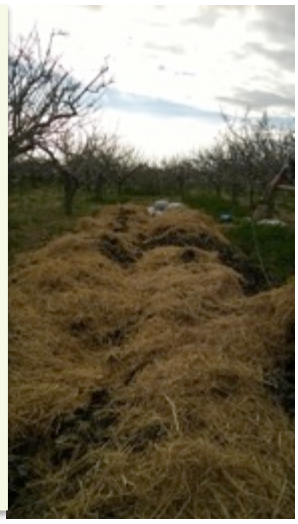
1. Apply the materials in layers, one above the other, alternately.

Applying the pistachio wastes

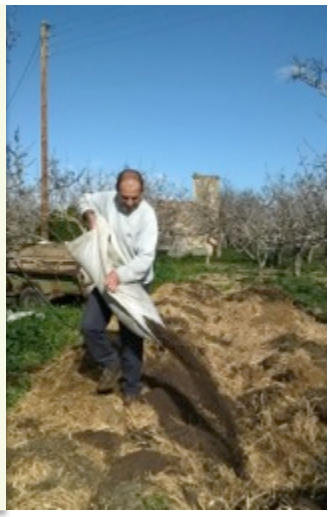
Adding the zeolite

Adding the straw

The straw layer above waste-, manure- and zeolite- layers



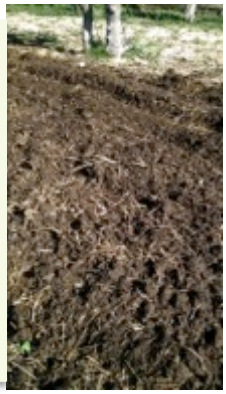
Preparing a new manure layer



2. Mixing of the layers and wetting. After finishing the application of the materials, mix and wet the mixture. The moisture of the mixture should be between 45 and 60%.

Mixing and wetting

A well-mixed compostable mixture



3. Protection of the mixture. Use covering composting textiles to divert precipitation and keep compost dry. Construction of a roof over the composting area could also be effective, but not so effective in keeping the compost warm and dry.

Covering composting textile (TOPTEX) to protect compost

Composting phase

A well-aerated compost pile has at least 5% oxygen content during the active phase of composting (ideally closer to 10%). Composts must be aerated, as aeration is key to successful composting. As microbial activity increases in the compost pile, more oxygen will be consumed. If the oxygen supply is not replenished, composting can shift to anaerobic decomposition, slowing of the composting process and foul odors. Oxygen monitoring equipment is available, but is expensive. However, temperature, odors and moisture are easy to measure and provide a good indication of active decomposition and adequate aeration.

Temperature should be monitored at least weekly (using a compost thermometer), as well as the moisture content and odor

Measure compost temperature by using compost-thermometers. When the temperature is above 62-65°C aerate the mixture by turning it several times

WINDROW TURNING FREQUENCY	
First 3-5 days	Turn daily
Next 3-4 weeks	Turn 1-3 times/week
Week 5 to End	Turn once/week (max)

During the active phase of composting, water will be given off as vapor when temperatures are high. A good practice is turning of the piles with simultaneous water addition. Moisture levels should be maintained so the materials are thoroughly wet but not waterlogged or dripping excessive water.

There are instruments and procedures for accurately determining moisture content, but as a rule, the materials are too wet if water can be squeezed out of a handful and too dry if the handful does not feel moist to the touch.

The optimum time to add water is during the aeration and turning operation

Different types of moisture meters

The importance of keeping the moisture content of the substrate above 40% to 45% is often overlooked in compost practice. It is important because moisture content is inhibitory at lower levels, and all microbial activity ceases at 12% moisture content (Dean, 1978).

Troubleshooting

If some condition is less than satisfactory or even inhibitory, then the temperature of the mass to be composted does not begin to rise or rises extremely slow after the material is windrowed. In such a situation, it is highly probable that the underlying problem either is that the moisture content of the mass is excessively high or that it is excessively low. A proliferation of malodours would be symptomatic of excessive moisture. Conversely, the absence of all odours would be indicative of excessively low moisture content. A possible cause not related to moisture could be an unfavorably high C/N ratio. The difficulty with that diagnosis is the fact that some increase in temperature would be detectable even though the C/N were high. A pH level lower than appropriately 5.5 or higher than about 8.5 could be a third possibility. High moisture content can be remedied by adding a

bulking material. An alternative is to intensify aeration. Aeration not only supplies needed oxygen, it also evaporates moisture. Addition of water is the obvious remedy for low moisture content. A high C/N ratio can be lowered by enriching the substrate with a highly nitrogenous waste (e.g. manure). Lime may be used to raise pH level.

An abrupt, sharp change in an operational parameter is symptomatic of an unfavorable development. Thus, an unplanned interruption of the exponential rise in temperature would indicate the development of an inhibitory situation such as excessive moisture in a windrow. Either inadequate aeration or insufficient moisture could account for an unscheduled slowing of the exponential temperature rise or shortening of the duration of the high-temperature period.

TABLE 4. Troubles, causes and solutions (Alberta, 2005)

Problem	Possible Causes	Solutions
The inside of the windrow is dry	Not enough water	Add water when turning the windrow
Temperature is too high	1. Low to moderate moisture	1. Add more water and continue turning the windrow
	2. The windrow is too big	2. Try to decrease the size of the windrow
Temperature is too low	1. Insufficient aeration	1. Turn the windrow more frequently to increase the air flow
	2. Wet condition of the windrow	2. Add more dry material
	3. Low pH	3. Add lime or wood ash and remix
Ammonia odor	1. High levels of N (C:N ratio less than 20:1)	1. Add high carbon material, such as sawdust, woodchips, or straw
	2. High pH	2. Lower pH by adding acidic ingredients (leaves) or avoid adding more alkaline materials such as lime and wood ash
Hydrogen sulphide odor	Windrow material is too wet and its temperature is too low	Add dry bulk material

When is the compost ready?

As the active composting phase subsides, temperatures gradually decline to ambient temperature. Mesophilic microorganisms recolonize the mixture and the compost enters the curing phase. The rate of oxygen consumption during curing phase declines to the point where compost can be stockpiled without turning. Organic materials continue to decompose and are converted to biologically stable humic substances-the mature or finished compost. Potentially toxic organic acids

and resistant compounds are also stabilized during curing.

A long curing phase is needed if the compost is unfinished or immature. This can happen if the windrow or the pile contained too little oxygen or either too little or too much moisture. Immature composts can contain high levels of organic acids and salts and have high C/N ratios as well as unacceptable pH values.

There is no clearly defined time for curing. Common practices in commercial composting operations range from 1 to 4 months. However, longer periods may be needed, depending on feedstock quality and environmental conditions.

By the time composting is completed, the windrow or the pile becomes more uniform and less active biologically although mesophilic organisms recolonize the compost.

The material becomes dark brown to black in colour. The particles reduce in size and become consistent and soil-like in texture. In the process, the amount of humus increases, the ratio of carbon to nitrogen (C/N) decreases, pH neutralizes, and the exchange capacity of the material increases (Misra et al., 2003). The rate of oxygen consumption declines to the point where compost can be stockpiled without turning.

Efficient compost use

Although applying compost on soil may significantly improve soil's properties (e.g. organic matter, water holding capacity, nutrients content, porosity), landspreading must always respect some preconditions and rules.

Therefore, prior use on soil, the following questions must be answered (Doula et al., 2016):

1. *What is the quality of the produced compost?*

   To answer this question, a complete chemical analysis of the produced compost must be performed. It is not recommended to apply compost on soil without knowing its composition. Therefore, when compost is ready, samples must be taken from different windrow or pile points and depths, appropriately mixed and analyzed for the parameters of TABLE 1.

2. *What is the level of soil fertility and which nutrients should be supplied for the specific type of cultivation?*

   To answer this question soil analysis should be performed annually, not only to assist farmers to identify the most appropriate cultivation practice but also in order to define any potential adverse effects caused to soil health due to previous or future application of organic materials, composts included. Having identified the level of soil fertility, quantified cultivation targets must be set.

3. *Given the cultivation targets, how much of the nutrients should be applied on soil and which are the most appropriate practices to be implemented?*

   In order farmers to benefit the most by compost use, they should exactly determine

what they are trying to achieve, e.g. restoration of the productivity of an eroded soil, provide supplemental nutrients to their cultivation, etc., and to determine what practical and workable combinations of organic materials and mineral fertilizers are most appropriate to accomplish the proposed task. Then farmers could proceed to the next stage and define the most appropriate cultivation practices for their case and special area's conditions.

For the development of sustainable cultivation practices, it should be kept in mind that soil must always maintain all its functions and its absorption capacity to ensure a sustainable system.

When considering of using composts and other organic materials in crop production or field application, then application rates must be carefully estimated and based upon soil fertility, crop requirements and waste specific characteristics. Irrigation water quality and composition should be also taken into account since irrigation water contains soluble salts; some of them are considered nutrients (e.g. potassium salts) or pollutants (e.g. heavy metals, nitrates).

4. What is the maximum permitted compost amount to be applied on soil?

The maximum amount of compost that a soil can afford based on its physicochemical properties should be estimated by considering the concentrations of compost's elements/substances as well as the concentration of these elements/substances in soil and define the one that is the restrictive factor for the application. Heavy metals should be also taken into account. The legislative framework of many countries defines specific amounts of heavy metals that can be added on soils annually, as well as the upper limits of heavy metals concentration in soils and composts. Therefore, heavy metals should be considered as potential restrictive parameters, as well. After the definition of the most restrictive element/substance, its concentration can be used for the estimation of the maximum waste amount to be distributed. For instance, this element/substance could be the one with the highest concentration or with the lowest threshold in soil or in the compost.

5. What is the annual rate of compost application?

The annual rate of application could be determined by taking into account the general fertilization rules. Considering the needed amount per unit area of each nutrient, the amount of waste that is theoretically needed to fulfill each nutrient requirement can be calculated. If, for example, the needed potassium amount is 300kg/ha and knowing the potassium concentration in waste, then the amount of waste that contains this quantity can be estimated. The same calculations must be repeated for all nutrients. The calculated nutrients' amounts will be, of course, different, but the lowest one should be added to the cultivation. The next stage is to compare this amount with the *maximum permitted* one (see above (4)). If the *maximum permitted*

waste amount is higher than the estimated *annual* one, then the latter can be applied on land. Otherwise, the amount to be distributed is the *maximum* one.

Having identified the appropriate compost amount (which, in fact, is derived from one nutrient), all other nutrients' quantities that are contained in this amount are re-estimated. It has to be highlighted that by using the above process, only one nutrient will be covered by the organic material and therefore mineral fertilizers should supplement the other nutrients.

6. What is the most appropriate time for application?

The time of application has to be defined considering the annual rainfall rate, intensity and distribution throughout the year and the temperature, in relation to water balance, soil properties and processes, microbial activity and compost decomposition.

Although farmers have, in general, experience in developing cultivation practices, however this experience is based mainly on traditional habits. Therefore, the cooperation with experts (agronomists) is recommended in order to ensure that the cultivation practices using composts or other organic materials will be the most appropriate given the local environmental, social and economic circumstances.

References

Alberta Agriculture, Food and Rural Development. (2005). "Manure Composting Manual" Prepared and Published by: Livestock Engineering Unit & Environmental Practices Unit Technical Services Division, Edmonton, Alberta Canada.

Böhm, R., Martens, W., Philip, W. (2000). Hygienische Relevanz von Keimemissionen bei Sammlung und Behandlung von Bioabfällen. (Hygienic relevance of spore emmissions during collection and handling of bio-waste) Abfalltagung 2000. Kassel University. MIC Baeza Verlag.

Cochran, B.J., Carney, W.A. (1996). "Basic principles of composting-What is composting?". LSU AgCenter-Research and Extension, Lousiana, USA.

Dean, R.B. (1978). European Manufacturers Display Systems at Kompost '77". Compost Sci., 19(2),18-22.

Doula, M.K. Elaiopoulos, K., Kouloumpis, P., Zorpas, A.A. (2015). Composting pistachio wastes: The use of clinoptilolite to improve compost quality. 5th International Conference on Environmental Management, Engineering, Planning and Economics (CEMEPE 2015), 14 - 18 June 2015, Mykonos Island, Greece.

Doula, M.K., Sarris, A., Hliaoutakis, A., Kydonakis, A., Papadopoulos, N.S., Argyriou, L. (2016). Building a Strategy for soil protection at local and regional scale-the case of agricultural wastes landsprading. Environmental Monitoring and Assessment, 188 (3), 1-14.

Misra, R.V., Roy, R.N., Hiraoka, H. (2003). On-farm composting methods. Published by Food and Agriculture Organization of the United Nations (FAO).

PEI (1996). Department of Environmental Resources and Department of Agriculture, Fisheries and Forestry. Province of Prince Edward Island Guidelines for Disposal of Cull Potatoes. March 1996.

Rynk, R. (1992). On-Farm Composting Handbook. Northeast Regional Agricultural Engineering Service Pub. No. 54. Cooperative Extension Service. Ithaca, N.Y.

Vermeer Corporation, (2008). " A practical guide to composting". (http://www.vermeer.com)

The project

“Sustainable strategies for the improvement of seriously degraded agricultural areas: the example of *Pistachia vera* L.”

AgroStrat

is co-funded by the European Commission and Greece

http://www.agrostrat.gr

This document should be cited:

M.K. Doula. (2016) “Composting at field: Guidelines for pistachio producers”. LIFE11 ENV/GR/951 project “Sustainable strategies for the improvement of seriously degraded agricultural areas: the example of *Pistachia vera* L.”

Athens, 2016