Scientific Papers. Series A. Agronomy, Vol. LXI, No. 1, 2018
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

EFFECT OF BIOCYCLIC HUMUS SOIL ON YIELD AND QUALITY PARAMETERS OF SWEET POTATO (*Ipomoea batatas* L.)

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Abstract

A field experiment was conducted on sweet potato (Ipomoea batatas L.) at the Agricultural University of Athens during the growing summer season 2017 to evaluate the effects of biocyclic humus soil on plant growth, yield as well as chemical constituents and quality parameters. The experiment was laid out in completely randomized design (CRD) with three replications of three treatments (untreated, inorganic fertilizer and biocyclic humus soil). A two-leaf cutting was placed into the treated soil to make a sweet potato plant. The highest sweet potato yield was obtained by using biocyclic humus soil with average total yield (35.6 t/ha) and average marketable yield (24.3 t/ha). There were no statistically significant differences between the treatments for the compression (Max Load 0.622-0.780 kN) and the penetration (Max Load 0.0439-0.0447 kN) tests on sweet potato tubers. Furthermore, measurements were implemented for the total nitrogen content of tubers with no statistical significant differences between treatments. The big difference in yield between sweet potato grown in humus soil and sweet potato treated conventionally probably is related to the fact that the structure of soil which is a clay loam soil was too compact for the cultivation of sweet potato, a disadvantage which has been compensated by using humus soil as substrate while substituting soil.

Key words*: biocyclic humus soil, Biocyclic Vegan Standard, sweet potato, Ipomoea batatas* (L.), *productivity and quality.*

INTRODUCTION

The total global sweet potato production in 2016 was more than 105 million tonnes (FAO-STAT, 2018) with China having the biggest share in production (about 66%). China and the U.S. are the fastest growing exporters. Though sweet potato is a traditional crop for many countries of the world (China, Mexico etc.) cultivation and consumption in European countries became more popular in the last decades. (Loebenstein, 2009). The European production is offered by four countries: Portugal, Spain, Italy and Greece with a total production of 52 thousand of tonnes in 2016. In the same year Greek sweet potato production was 3.3 thousand tonnes cultivated in an area of 164 ha (FAO-STAT, 2018).

Sweet potato origins are found in Central or Northwestern South America due to the occurrence of Tropical Forest root crop agriculture (O'Brien, 1972). It was shown that after an analysis of sweet potato genotypes with RAPD markers the dispersal of sweet potato has been achieved more through the Central/Caribbean genopool (Gichuki et al., 2003).

The scientific name of sweet potato is *Ipomoea batatas* (L.) Lamk and belongs to the *Convolvulaceae* family. *Ipomoea batatas* can be adjusted in many climate zones such as warm humid tropics or mild sub-temperate zones also at an altitude of 2000 meters. The plant of sweet potato prefers a sandy loam ground and is cultivated often on mounds or ridges (Lim, 2016).

The edible parts of the sweet potato plant are the roots or tubers but also the sweet potato leaves and green tips. Sweet potato flour or starch is also used as an ingredient for secondary food products. As the sweet potato is considered to be one of the most healthiest food because of its health-giving additives it seems likely it could play an important role in a balanced and healthy human diet (Padmaja, 2009).

Global organic food and drink sales are increasing in scope year by year with an annual growth of 10% for 2015 with 81.6 Billion U.S. dollars sales (Amarjit, 2017). But also, the number of producers has increased by 7% in 2015 (Lernoud, 2017).

To control and compare all these organically grown products several standards and regulations have been developed over the past decades worldwide, especially in 2016 there were 87 national organic standards. All these recognized standards should follow the international approved guidelines of the Codex Alimentarius. Following this Codex Guidelines ensures the comparability of all these different standards (Huber, 2017).

A call is made to all stakeholders in the organic sector to participate in the renewal and the advancement of organic visions through the idea of IFOAM's Organic 3.0. The movement of Organic 3.0 promotes a more sustainable management through the hole agricultural sector with innovation being the driving force (Arbenz, 2016).

As shown in the study of Bilalis et al. (2017) organic agriculture could play a pivotal role in the introduction of innovative crops into the Mediterranean area as part of the implementation of measures for adaptation to climate change. In this context further field studies are needed to support an integrated approach of cultivations with a high interest in organic production such as sweet potato under the special Greek-Mediterranean conditions.

Even though, the consumption and the interest in cultivation of sweet potato to cover the needs of both the local market and exports is becoming bigger no scientific research has been done in Greece yet to cover this growing agricultural sector. With this experiment a first step is done in this direction.

In several researches the positive effect of organic matter through mulching or organic fertilization in the improvement of sweet potato production has been shown (Janssens et al., 2014; Nwosisi et al., 2017).

The organic cultivation of sweet potato in this experiment was practiced according to the Biocyclic Vegan Standard to meet the special needs and particular conditions of Greek agriculture.

The Biocyclic Vegan Standard became as a global standard a full member of the IFOAM's Organic Family of Standards in December 2017. This standard based on the German pioneer Adolf Hoops (1932-1999) was developed and practiced under the Greek Mediterranean conditions. From the very beginnings the biocyclic idea included a vegan aspect which were brought into play in the past years after combining initiatives from the organic vegan movement in agriculture. The Biocyclic Vegan Standard promotes a more lifecycle orientated organic agricultural model by excluding animal production (as known in the form of husbandry) and animal products from the hole agricultural production chain. The constant rise of soil fertility by increasing soil organic matter or humus is of high-priority. This is done by using mature compost or biocyclic humus soil together with green manuring and mulching (Biocyclic-Vegan Network, 2018).

Humus soil is characterized as a mature compost which has gone through a post-maturing process. The stability of this material empowers the possibility even to grow directly young plants and seedlings as it is very root-friendly. According to the Biocyclic Vegan Standard all materials used for the production of humus soil should be of plant origin (Biocyclic-Vegan Network, 2018)

The purpose of this study was to evaluate the effects of biocyclic humus soil application on total yields, texture through compression and puncture test and the content of some nutrients of sweet potato tubers.

MATERIALS AND METHODS

From May till September 2017 a field experiment was conducted at the organic certified experimental field of the Agricultural University of Athens (Latitude: 37°59′ 1.70″ N, Longitude: 23°42′ 7.04″ E, Altitude: 30 m above sea level) in Votanikos, Athens. Mean temperature and precipitation for the growing season are shown in Figure 1.

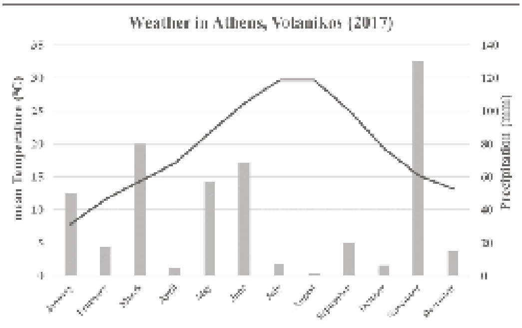

Figure 1. Meteorological data (mean temperature and precipitation) recorded by the weather station of Agricultural University of Athens

The soil was clay loam (29.8% clay, 34.3% silt and 35.9% sand) (Bouyoucos, 1962) with pH (1:1 H_2O) 7.29, nitrate-nitrogen (NO_3-N) 12.4 mg kg^{-1} soil, available phosphorus (P) 13.2 mg kg^{-1} soil, available potassium (K) 201 mg kg^{-1} soil, 15.99% $CaCO_3$ and 1.47% organic matter (Wakley, Black, 1934).

In this experiment olive pomace (30%), olive-tree leaves (50%) as a by-product of olive-mills equipped with two-phase centrifugal decanters, grape marc (10%) and ripe humus soil (10%) were used to derive a mature compost of rotting degree V (Table1). An industrial windrow composting procedure like that described by Manios (2004) was followed. Materials were placed in a windrow of 3 m wide by 1.5 m high and 150 m length and watered at 60% of their water holding capacity weekly for the first 3 months and every 4 weeks for the next 2 months of composting. To obtain a soil-like state beyond substrate maturity a post-maturing process followed for the next 3 years. In this stadium humus soil can be used especially in horticulture for direct planting.

The three treatments biocyclic humus soil (HS), Inorganic fertilizer 42-0-0 (IN) and the untreated control (CON) of the trial were arranged in a Completely Randomized Design with three replications. Each of 9 plots had a size of 2.0 m x 3.6 m. On the 8th of Mai 2017 6 sweet potato slips were planted in every plot in a distance of 1.2 m x 0.66 m. As a slip is a rooted sweet potato cutting described. Each slip had been produced from a two-leave sweet potato cutting and were planted into pots with biocyclic humus soil for one week to produce roots before planting in the end field position. The leaves of the cuttings were shortened and misted every 5 hours for the first 3 days and then regularly irrigated.

Soil was prepared by ploughing at a depth of about 0.25 m. Small round embankments were prepared in each planting position. A day before planting, inorganic fertilizer was applied by hand and the biocyclic humus soil was incorporated into final planting positions. 340 g of inorganic fertilizer in form of urea 42-0-0 was applied on every plot of 7.2 m^2 which corresponds to 200 kg N/ha.

15 liters of biocyclic humus soils was applied in every planting position to obtain the direct contact of the plant roots with the material. Irrigation was done every 3 to 4 days by hand and weeding was necessary every 3-4 weeks. No plant protection application was needed.

The sweet potato tubers were harvested and the vines emmoved by hand 137 days after planting on the 22th of September. The roots were stored for one week for curing (28°C, 80-90% relative humidity) and then stored for one month (15°C, 80-90% relative humidity) before doing measurements.

Table 1. Analysis of biocyclic humus soil on dry basis and in water extraction

Analysis description	On dry basis	Extraction with 600 ml deionised water from 360 g humus soil
Total Nitrogen (N), g/100 g	2.8	0.015
P_2O_5 soluble in inorganic acids (total), g/100 g	0.8	0.002
Total Potassium (K), g/100g	0.6	0.034
Electrical Conducitivity (1:5), pH units	7.6	
Cation Exchange Capacity (C.E.C.), meq Na/100 g	91.9	

Sweet potato tubers and vines were weighed after harvest to determine total yields with digital scale (Kern TB, Kern & Sohn GmbH, Balingen-Frommern, Germany).

Harvested tubers were classified according to weight of tubers in marketable sweet potato tubers (>100 g) and the non-marketable sweet potato tubers (<100 g)

Cylindrical samples with diameters of Ø 2.5 cm were cut from the central region of sweet potato tubers using a cork borer of the same diameter and then trimmed with a stainless cutting knife to a height of 2 cm. For each experiment a sweet potato cylindrical sample was placed on the bottom parallel plate and compressed. Compression experiments were performed in 3 replications.

The test was carried out between the standard Instron stainless steel polished platens (upper plate: 4 cm in diameter and designed for fracture testing) of a Instron Universal Testing Machine (Instron Model 1011, Canton, MA, USA) using a 5 kN load cell and a flat 15 mm diameter compression plunger. During compression experiments cross-head speed was 6 mm/min. Maximum force to break (N), displacement at maximum force (mm), and the initial slope (N/mm) of the curves were chosen as parameters to evaluate texture.

To measure puncture (penetration) whole sweet potato samples were placed on the stainless-steel platform of a Instron Universal Testing Machine (Instron Model 1011, Canton, MA, USA). A puncture probe with 4 mm diameter was used to punch the sweet potato using a constant speed of 6 mm/min and a 5 kN load cell. Puncture experiments were performed in 3 replications. As in compression test maximum force to break (N), displacement at maximum force (mm), and the initial slope (N/mm) of the curves were chosen as parameters to evaluate texture.

Two samples of stored sweet potato tubers were cleaned with fresh water and peeled and then sliced to 3 mm thickness and then mixed. The samples were dried in a hot air oven at a temperature of 60°C for 24 h. The dried samples were milled in attrition mill to obtain fine flour used for chemical analysis. Nitrogen (N) concentration was obtained using the Kjeldahl method (AOAC, 2006),

Potassium (K) was determined by a flame Spectrophotometer. Calcium (Ca), and Iron (Fe) were determined by atomic absorption spectrometry.

RESULTS AND DISCUSSIONS

Figures 2 and 3 shows average total and marketable yield, average tuber number per plant, but also the maximum load for compression and puncture tests and the total content of nitrogen in potato tubers of all three treatments.

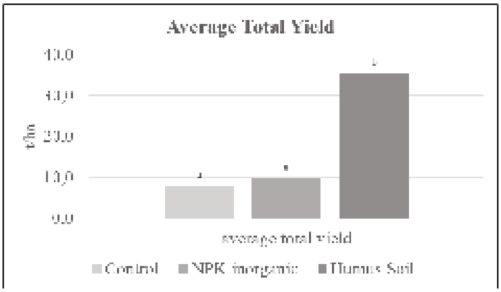

Figure 2. Average total yield of sweet potato (5.5 plants per m^2)

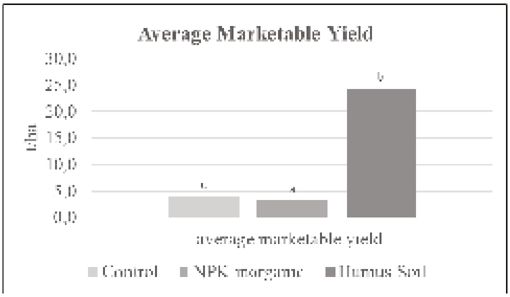

Figure 3. Average marketable yield of sweet potato (5.5 plants per m^2)

Analysis of the yield responses showed statistical significant differences ($P < 0.05$) of total and marketable yield as well as for the average potato tuber number per plant with treatments with humus having the biggest rates. Average total yield were 35.6 t/ha and 9.9 t/ha measured for a density of 5.5 plants per m^2 and average marketable yield 24.3 t/ha and 3.2 t/ha for treatments with humus soil and inorganic fertilizer respectively. Sweet potato yields depend a lot on the cultivated variety but also on the location of the site. For example, the average yield of sweet potato for the United States was 21.2 t/ha for 2008 ranging from 35.9 t/ha in California and 18.5 t/ha in North Carolina (Smith et al., 2009). The average yield for Greece was 18.6 t/ha in 2006 and 20 t/ha for 2016 (FAOSTAT, 2018). The average sweet potato yield in the world has been doubled from 7.3 t/ha to 13.87 t/ha from 2001 to 2006 (Srinivas, 2009). According to Nwosini et al. (2017) a field experiment in the USA in Nashville was performed to evaluate yield performance of organic sweet potato varieties in various mulches which indicated that the average marketable yield was between 20 and 28 t/ha due to different mulching techniques and between 4 and 40 t/ha affected by the sweet potato variety. The big difference in yield between sweet potato grown in humus soil and sweet potato treated conventionally probably is related to the fact that the structure of soil which is a clay loam soil was too compact for the cultivation of sweet potato, a disadvantage which has been compensated by using humus soil as substrate while substituting soil.

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The mean values of maximum load needed in the compression test ranged from 0.623 to 0.787 but there was no significant difference found for the different treatments (Table 2). No statistical significant differences were found also for maximum load value performed in the puncture test. Total nitrogen content varied from 0.192% for the control to 0.304% for the inorganic treatment but with no statistical significant difference ($P < 0.05$).

As shown in Table 2 there were no found correlations between yield parameters and physicochemical properties.

Table 2. Effect of fertilization on qualitative and quantitative parameters of sweet potato tubers

Treatment	**Average total yield (t/ha)**	**Average marketable yield (t/ha)**	**Average tuber number per plant**	**Compression Max Load (kN)**	**Puncture Max Load (kN)**	**Total content of N (%)**
Control	8.2 a	4.1 a	3.6 a	0.665 a	0.0443 a	0.192 a
NPK inorganic	9.9 a	3.2 a	4.0 a	0.623 a	0.0439 a	0.304 a
Humus Soil	35.6 b	24.3 b	6.4 b	0.787 a	0.0447 a	0.229 a

Table 3. Correlation coefficient between yield parameters and physicochemical properties.
Marked correlations are significant at p < 0,05000 N=9

	Average total yield (t/ha)	**Average marketable yield (t/ha)**	**Average tuber number per plant**	**Compressi on Max Load (kN)**	**Puncture Max Load (kN)**	**Total content of N (%)**
Average total yield (t/ha)	1.0000 p= ---					
Average marketable yield (t/ha)	0.9772 p=0.000	1.0000 p= ---				
Average tuber number per plant	0.9157 p=0.001	0.8212 p=0.007	1.0000 p= ---			
Compression Max Load (kN)	0.6026 p=0.086	0.6078 p=0.083	0.4882 p=0.182	1.0000 p= ---		
Puncture Max Load (kN)	0.0932 p=0.812	0.1349 p=0.729	0.0519 p=0.894	-0.2091 p=0.589	1.0000 p= ---	
Total content of N (%)	-0.1087 p=0.781	-0.1045 p=0.0789	-0.1611 p=0.679	-0.4873 p=0.183	0.2906 p=0.448	1.0000 p= ---

To identify factors affecting the level of Average marketable yield multiple regression analysis was performed to build the regression equation as shown below:

Average marketable yield = 5.52202 + 1.3943*(Average total yield) – 0.4556*(Average tuber number per plant)			
St. error:	(2.24837)	(0.10954)	(0.10954)
P(level)	(0.049)	(0.000014)	(0.005949)
Std. Error of estimate: 1.3366 F (2.6) = 254.95			

The regression equation shows the existence of two predictors: The Average total yield which has a positive correlation relation to Average marketable yield and the Average tuber number per plant which has a negative correlation relation to Average marketable yield. This means that as the Average tuber number increases the Average marketable yield is affected into the opposite way.

CONCLUSIONS

Yield components as well as quality parameters of sweet potato tubers grown into biocyclic humus soil were determined in comparison with tubers grown conventionally.
Total and marketable yield as well as the tuber number per plant were significant higher using biocyclic humus soil (photos 1 and 2).

Photo 1. Sweet potato tubers
(inorganic fertilizer)

Photo 2. Sweet potato tubers
(humus soil)

Marketable yield in this study was 24.3 t/ha for biocyclic humus soil which is comparable to the average marketable yields of sweet potato grown in Greece 20 t/ha.
Though, other textural parameters and the total nitrogen content didn’t show any statistical difference. Because of the clay loam soil of the experimental site the conventional yield and plant development was not sufficient.
There is a potential for using humus soil as a growing substrate to compensate adverse growing conditions for certain crops like sweet potato in an inadequate soil environment.

This experiment shows us that it is worth developing further research to generate more knowledge about both, the usage of humus soil in agriculture and the characteristics of humus soil as such.

ACKNOWLEDGEMENTS

Special thanks have to be addressed to all those who helped to implement the project and especially to the Biocyclic Park in Kalamata for providing the humus soil, to Prof. Emmanuel Anagnostaras from the Laboratory of Engineering, Processing and Preservation of Foods of the Agricultural University of Athens and the Institute of Food Technology, Hellenic Agricultural Organization-Demeter (N.AG.RE.F.) for the cooperation.

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