OPEN ACCESS

African Journal of Agricultural Research

13 December, 2018
ISSN 1991-637X
DOI: 10.5897/AJAR
www.academicjournals.org

ACADEMIC JOURNALS
expand your knowledge

About AJAR

The African Journal of Agricultural Research (AJAR) is a double blind peer reviewed journal. AJAR publishes articles in all areas of agriculture such as arid soil research and rehabilitation, agricultural genomics, stored products research, tree fruit production, pesticide science, post-harvest biology and technology, seed science research, irrigation, agricultural engineering, water resources management, agronomy, animal science, physiology and morphology, aquaculture, crop science, dairy science, forestry, freshwater science, horticulture, soil science, weed biology, agricultural economics and agribusiness.

Indexing

Science Citation Index Expanded (ISI), CAB Abstracts, CABI's Global Health Database
Chemical Abstracts (CAS Source Index), Dimensions Database, Google Scholar
Matrix of Information for The Analysis of Journals (MIAR) Microsoft Academic
ResearchGate, The Essential Electronic Agricultural Library (TEEAL)

Open Access Policy

Open Access is a publication model that enables the dissemination of research articles to the global community without restriction through the internet. All articles published under open access can be accessed by anyone with internet connection.

The African Journal of Agricultural Research is an Open Access journal. Abstracts and full texts of all articles published in this journal are freely accessible to everyone immediately after publication without any form of restriction.

Article License

Memberships and Standards

Academic Journals strongly supports the Open Access initiative. Abstracts and full texts of all articles published by Academic Journals are freely accessible to everyone immediately after publication.

Crossref is an association of scholarly publishers that developed Digital Object Identification (DOI) system for the unique identification published materials. Academic Journals is a member of Crossref and uses the DOI system. All articles published by Academic Journals are issued DOI.

Similarity Check powered by iThenticate is an initiative started by CrossRef to help its members actively engage in efforts to prevent scholarly and professional plagiarism. Academic Journals is a member of Similarity Check.

CrossRef Cited-by Linking (formerly Forward Linking) is a service that allows you to discover how your publications are being cited and to incorporate that information into your online publication platform. Academic Journals is a member of CrossRef Cited-by.

Academic Journals is a member of the International Digital Publishing Forum (IDPF). The IDPF is the global trade and standards organization dedicated to the development and promotion of electronic publishing and content consumption.

Contact

Editorial Office: ajar@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/AJAR

Submit manuscript online http://ms.academicjournals.org

Academic Journals

73023 Victoria Island, Lagos, Nigeria

ICEA Building, 17th Floor, Kenyatta Avenue, Nairobi, Kenya

Editors

Editorial Board Members

Table of Content

Vol. 13(50), pp. 2808-2817, 13 December, 2018
DOI: 10.5897/AJAR2018.13581
Article Number: 56B087159500
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

A research on the determination of productivity levels of tomato grown areas

Tuncay Demirer

Laboratory Technology Program, Alasehir Vocational School of Chemistry and Chemical Process Technology Department, Manisa Celal Bayar University, Post Code: 45600, Alaşehir-Manisa / Turkey.

Received 1 October, 2018; Accepted 30 October, 2018

The research was conducted in tomato-growing lands of Lâpseki, Ezine, Bayramiç and Central districts of Çanakkale province, Turkey. The aim of the study is to check the suitability of the field for tomato farming and to produce a solution if there is a problem. Disturbed soil samples were taken from 114 points with certain coordinates, at a depth of 0 to 30 cm, and analyses were performed. In the soil samples, texture, soil reaction (pH; 1:2.5), calcium carbonate ($CaCO_3$%), phosphorus (P; kg.ha^{-1}), cation exchange capacity (CEC; meq.100 g^{-1}), iron (Fe; ppm), manganese (Mn; ppm), zinc (Zn; ppm), copper (Cu; ppm) and clay (%) analyses were conducted, and characteristic maps of the region were prepared according to the results of the analyses. Based on these results, the present condition and suitability of the soils were evaluated, and simple statistics along with correlations of the analyzed parameters were examined. For the problems of the area, in low pH areas, it was deemed necessary to apply calcium carbonate ($CaCO_3$) or calcium hydroxide [$Ca(OH)_2$] together with physiological alkaline fertilizers. As per the high pH areas, it was necessary to apply elemental sulfur together with physiological acid fertilizers. It was also concluded that Zn application was necessary for the 43.85% of the area with Zn deficiency.

Key words: Efficiency level, nutritional status, plant nutrition, tomato.

INTRODUCTION

There is a big question about whether conventional farming practices can provide food for a world population expected to exceed 7.4 billion by 2020 (Pendey and Chandra, 2013). For this reason, it has become a necessity to increase agricultural production. The agricultural production consists of animal and plant production, while plant production is made up of fruits, vegetables, grains and industrial plants. Vegetables, particularly tomatoes, have a great significance in human nutrition and health. Tomato (*Solanum lycopersicum*) is an annual plant, which grows 1-3 m tall, among the Solanaceae family, native to central, south, and north America ranging from Mexico to Peru (Guntekin et al., 2009). Considering the global plant production, tomato is the third most consumed and popular vegetable following potato and sweet potato (FAOSTAT, 2018).

A total of 12750 tons of tomatoes, about 8750 tons of table tomatoes and 4000 tons of paste tomatoes, were produced in 2017 in Çanakkale, which covered 2.56% of the vegetable fields of Turkey (TSI, 2017). In addition,

E-mail: demirert@gmail.com. Tel: +90 236 654 12 01.

Figure 1. Geographical location and map of the research area.

among the vegetables, tomatoes have taken the first place with 12,750,000 tons of production in 2017 year (TSI, 2017). Therefore, tomato is the most important vegetable of the research area (TSI, 2017). Popularity of tomato depends on its chemical content as 93-95% of a tomato is composed of water, and 5-7% composed of inorganic compounds, organic acids (citric and malic acid), alcohol-insoluble proteins, cellulose, pectin, polysaccharides, carotenoids and lipids (Petro-Turza, 1987). It is an important source for human nutrition since it contains potassium, organic acids, and vitamins A and C at high levels (Moreno et al., 2008).

Efficiency is required for a qualified agriculture and quality products. This is only possible with proper fertilization together with other applications. In the ideal soils for tomatoes; pH: 6.0 - 6.5; texture: composed of combination of sand-loam or sand-loam-clay; lime: <5%; CEC: 15-20 meq.100 g^{-1}; P: > 90 $kg.ha^{-1}$; exchangeable Zn: 1-2 ppm; Fe: 2.5-4.5 ppm; Mn: < 10 ppm; Cu: > 0.2 ppm and the clay should be <35% (Kacar, 2012). On the other hand, soil fertility varies in different places (Mandal et al., 2015). Therefore, nutrients and microorganisms in the soil play an important role in improving soil quality (Sun et al., 2011). Farmers may excessively use inorganic and organic fertilizers and pesticides in order to harvest good yield. Particularly, the continuous use of chemical fertilizers increases the concentration of heavy metal in the soil (Arya and Roy, 2011).

The aim was to ensure controlled chemicals needed to protect the environment and to grow quality products. Determining the character of the soil is the first step in this process. Therefore, this research study was carried out to determine the soil character of the study area, and to suggest a solution if there was a problem.

METHODOLOGY

The research was conducted in Lâpseki, Ezine, Bayramiç and central districts of Çanakkale province. Çanakkale is a neighbor to Edirne and Tekirdağ provinces on the European side of Turkey, while it only neighbors Balıkesir on the Anatolian side. The city is located between longitudes 25°40'- 27°30' East and latitudes 39°27'- 40° 45' North (Figure 1). The large part of its territory is on the Anatolian side and its coastal length is 671 km (TSI, 2017). Mediterranean climate largely prevails in Çanakkale. However, because it is located in the north-west, it is colder in the winter compared to the Mediterranean climate. The lowest temperature falls to 6.4°C in February, while the highest temperature is about 41.7°C in August. Çanakkale has an average annual temperature of 15.2°C and an average humidity of 72.6%. There are more winds in Çanakkale than its neighboring provinces. In the winter season, there are very little snow falls and even if it snows, it stands on the ground up to one week. Rainfalls mostly occur during December, November, January and February (TSI, 2017). Climate is also very suitable for vegetable farming. Çanakkale province has a total area of 9933 km^2, 55% of which is comprised of forests. The remaining land consists of arable lands, meadows, and pastures. Just like in the climate, the vegetation is Mediterranean vegetation (TSI, 2017).

In this research, the coordinates of 114 locations to be studied were initially identified on the maps (1/100000) of the region. Locations of the identified points were found by GPS and marked. Mixed soil samples were taken from the 114 points at a depth of 0 to 30 cm (Kacar, 2012).

After gathering, soil samples were sent to the laboratory for then air-drying. Stones, plants and animal remains were picked out. These samples were then milled and sieved with a 10-mesh sieve (Kacar, 2012). Subsequently, they were analyzed. In the soil samples, texture and clay percentage were detected by the hydrometer method (Bouyoucos, 1962); soil pH was determined by using 1:2.5 soil-water suspension method (Jackson, 1973); % $CaCO_3$ was obtained by the Scheibler Calcimeter (Kacar, 2012); available phosphorous by Olsen et al. (1954) method and DTPA extractable Zn, Fe, Mn and Cu were determined with the standard method given by Lindsay and Norvell (1978). The results of the analysis of soil samples belonging to the research area were given

collectively in Table 1. In addition, the productivity maps and graphs of the research area were separately drawn according to the results (Figures 2 and 3). Correlations between the obtained parameter values (Table 2) and descriptive statistics (Table 3) were investigated with MSTAT statistic program (Akdemir et al., 1994).

RESULTS AND DISCUSSION

Four different soil textures were identified in the research area (Table 1 and Figure 2). Of the soil, 42.9% was identified as sandy, 29.8% as loamy-sand, 11.6% as sandy-loam and 11.6% as sandy-clay-loam (Bouyoucos, 1962). According to the analyses, 84.3% of the area is composed of sand and sand-loam mixture (Table 1 and Figure 2). Texture, which does not easily change, is an important physical property that affects the land character the most. This property is directly related to water, air and heat, and it significantly affects the nutrient reserve (Brady and Weil, 2008). A texture consisting of sand-loam or sand-loam-clay combinations is suitable for vegetable agriculture; thus, there is no problem for tomato in this respect (Güneş et al., 2013).

In the research, the pH value was determined to be varying between 4.6 and 8.1, and the average was found to be 6.7 (Table 2). The pH value was determined lower than 5.5 for 12.2%, higher than 6.5 for 58.7% and between 5.5 and 6.5 for 29.1% (Table 1, Figures 2 and 3). In this range, there would be no problem in retrieving macro and micro elements. Soil pH is one of the most important factors in the relationship between soil chemistry and nutrients, and in the intake of elements (Güneş et al., 2013).

The ideal soil pH should be between 6.0-6.5. If pH is higher than 6.5, the plant's intake of metallic micro nutrients (Fe, Zn, Mn, Cu) and boron (B) becomes more difficult and it decreases. However, if the pH is lower than 5.5, the phosphorus (P) and molybdenum (Mo) cannot be taken by the plant (Kacar and Katkat, 2010). When Table 3 was examined, a statistically insignificant negative correlation was observed between pH and Fe, Mn, and P. In the areas with the pH above 6.5, 1000-2000 kg ha^{-1} elemental sülfür should be used, and the fertilizers should be chosen in physiological acidic character. On the other hand, in areas with the pH value below 6.5, 1000-2000 kg ha^{-1} $CaCO_3$ or $Ca(OH)_2$ and fertilizers in physiological alkaline character should be used (Kacar and Katkat, 2010). When Table 3 was examined, a statistically insignificant negative correlation was observed between pH with Fe, Mn, and P. In the areas with the pH value above 6.5, 1000-2000 kg ha^{-1} elemental sülfür and the fertilizers in physiological acidic character should be used. On the other hand, in areas with the pH value below 6.5, 1000-2000 kg ha^{-1} $CaCO_3$ or $Ca(OH)_2$ and fertilizers in physiological alkaline character should be used (Kacar and Katkat, 2010).

The lime [Calcium Carbonate ($CaCO_3$%)] in the study, ranged from 0.1 to 41.8%, while its average was detected as 10.95% (Table 2). In an ideal soil, the lime content should not exceed 5% (Brady and Weil, 2008; Kacar and Katkat, 2010). However, there is no problem at the level of lime up to 15%. In 33.33% of the study area, lime has exceeded 15% (Table 1, Figures 2 and 3). Except for the 33.33%, the research area does not have a problem concerning the lime under the conditions that correct feeding and pH control is conducted. Phosphorus is bound at 33.33% of the research area. In addition, Zn, Fe and Mn are taken at low levels (Güneş et al., 2013). The negative relationship between lime and P, Fe, Mn, and Cu (Table 2) can be explained by the high lime content of the soils in the region (Güneş et al., 2013).

Moreover, a proportional formation was observed between lime and pH. It was suggested to use sulfur and organic acid for problematic soils (for 33.33%) in the research area (Güneş et al., 2013).

Cation Exchange Capacity [CEC (meq.100 g^{-1})] varied from 4.2 to 31.6 in the research, and the average was determined as 13.65 meq.100 g^{-1} (Table 2). In 33.33% (sand) of the research area, CEC was found to be lower than 10 meq.100 g^{-1}; in 29.84% (loamy-sand), it was detected as 10-15 meq.100 g^{-1}; in 19.29% (sandy-loam), it was determined as 15-20 meq.100 g^{-1}; whereas in 17.54% (sandy-loamy-clay), it was higher than 20 meq.100 g^{-1}. CEC increased as the clay rate increased in the soils (Table 1). Rathore et al. (2017) have found similar results. According to the results of the analysis, it was found that 33.33% of the research area was inadequate (< 10 meq.100 g^{-1}), 49.13% was adequate (10-20 meq.100 g^{-1}) and 17.54% was high (>20 meq.100 g^{-1}) (Table 1, Figures 2 and 3). In the soil, where CEC is low, applying compost (20 ton ha^{-1}) or leonardite (20-30 ton ha^{-1}), which are the sources of organic matter will be very useful. Additionally, though not statistically significant, a negative relationship between CEC and Fe, Mn, P, a positive low relationship between CEC and Zn, Cu, and a positive high relationship between CEC and clay were determined, respectively (Table 3) (Kacar and Katkat, 2010).

Phosphorus (P) content of soil samples ranges from 105.0 to 2147.0 kg.ha^{-1}, with an average of 416.8 kg ha^{-1} (Table 2, Figures 2 and 3). According to Kacar (2012), phosphorus level determined in the research area was found to be sufficient (P ≥ 90 kg ha^{-1}) (Güneş et al., 2013). This is because of the suppression of the lime and pH factor, which inhibits phosphorus intake (Güneş et al., 2013). It can be explained by the accumulation of dicalcium phosphate or tricalcium phosphate with the repetitive application of phosphorus in each production year (Kacar and Katkat, 2010; Güneş et al., 2013). In addition, although not statistically significant, a negative correlation was detected between CEC and Fe, Mn, P, a positive low correlation between CEC and Zn, Cu, and a high correlation between CEC and clay (Table 3). It is necessary to increase the solubility of the Phosphorus. For this purpose, sülfür, leonardite, organic acids or

Table 1. Analysis results of research area samples according to coordinates.

Samples no	Coordinate X	Coordinate Y	Soil reaction pH	$CaCO_3$ (%)	CEC (meq.100 g^{-1})	P $kg.ha^{-1}$	Zn ppm	Cu ppm	Fe ppm	Mn ppm	Clay %	Texture
1	472700	4465800	7.8	40.5	17.6	10.5	0.8	1.1	2.0	1.9	15	SL
2	472500	4465400	7.6	41.3	18.3	14.8	0.6	0.5	1.8	2.1	19	SL
3	472050	4465000	7.3	17.4	13.4	13.8	0.9	0.5	2.0	2.4	13	LS
4	473775	4466700	7.6	16.7	14.1	40.1	1.2	0.6	2.0	1.8	13	LS
5	473800	4466700	7.5	39.7	16.6	29.2	0.8	2.3	1.5	1.7	16	LS
6	468300	4455200	7.7	36.2	16.2	30.9	0.7	0.4	1.1	1.7	15	LS
7	465500	4455200	7.6	2.2	12.3	44.7	0.7	2.0	1.2	2.0	11	LS
8	469500	4455500	6.7	3.2	24.9	36.8	0.8	0.5	3.5	2.9	26	SCL
9	466700	4453700	5.8	0.1	16.1	39.5	0.6	1.0	4.5	7.2	13	LS
10	466700	4454700	6.2	0.1	15.7	43.3	0.5	0.5	4.8	5.4	16	SL
11	467500	4454600	6.3	0.2	15.8	30.0	1.5	2.6	3.5	5.3	13	LS
12	461500	4450500	6.3	0.1	16.3	40.0	1.3	2.6	4.0	5.0	13	LS
13	460600	4450480	7.1	23.6	13.7	35.2	0.8	1.1	4.4	3.2	11	LS
14	458400	4450800	7.7	32.6	11.9	33.8	0.6	0.5	2.0	2.6	12	LS
15	459500	4451600	7.6	1.2	13.3	57.4	0.6	0.8	2.6	2.2	15	LS
16	460300	4451700	7.7	1.0	18.1	19.4	0.5	0.7	1.5	1.9	20	SL
17	461650	4451850	7.8	36.6	31.3	28.9	2.6	0.7	1.6	1.4	32	SCL
18	462600	4451700	7.6	29.1	31.6	35.0	1.7	0.9	2.6	1.6	34	SCL
19	460700	4449300	7.7	30.5	14.9	36.3	0.8	0.5	2.1	1.6	14	LS
20	458600	4449500	7.4	21.5	13.8	35.6	0.5	0.4	2.6	1.3	15	LS
21	458500	4450600	7.6	27.2	13.0	36.4	0.9	1.5	1.0	1.5	12	LS
22	442400	4429300	7.5	28.6	14.8	47.2	0.7	0.8	2.0	1.7	15	LS
23	441500	4428600	7.7	1.6	12.9	30.9	0.6	1.1	2.5	1.2	14	LS
24	440800	4428100	7.8	1.9	13.7	35.0	0.7	1.3	2.4	1.8	15	LS
25	429500	4422500	6.6	0.2	13.1	29.4	1.3	2.4	4.1	4.3	12	LS
26	429500	4420500	6.0	0.2	11.4	32.5	0.9	1.7	2.4	5.9	10	LS
27	438500	4417300	6.9	1.3	13.7	24.6	0.7	1.9	5.1	3.8	13	LS
28	438450	4416500	7.6	0.7	21.8	40.7	0.9	1.8	4.3	2.7	21	SCL
29	437300	4416450	7.6	38.2	13.2	37.4	0.6	1.1	1.7	2.3	13	LS
30	438700	4415750	7.5	23.9	18.3	45.6	0.7	0.6	1.6	2.9	20	SL
31	438500	4415350	7.6	2.9	14.5	32.5	0.9	1.2	2.0	1.8	13	LS
32	434700	4415300	7.4	3.5	21.2	22.7	0.5	0.8	1.4	3.1	22	SCL
33	434600	4413800	7.8	9.2	11.4	28.4	0.7	0.8	2.1	1.7	9	S
34	435400	4413450	7.2	8.8	12.1	46.6	0.7	0.5	2.6	2.4	10	S
35	435500	4412500	7.3	1.5	10.9	40.7	1.4	1.5	2.9	2.4	8	S

Table 1. Contd.

36	435300	4415100	7.8	3.1	10.1	92.4	1.0	1.1	1.9	1.8	8	S
37	430500	4412500	6.8	1.1	16.6	214.7	1.0	1.1	3.9	4.1	16	SL
38	428500	4413500	6.6	0.2	27.1	148.6	2.4	0.6	3.8	5.2	30	SCL
39	428600	4412450	6.8	0.5	29.3	145.5	2.8	2.1	8.1	7.7	30	SCL
40	431000	4406700	7.1	0.7	11.1	152.7	1.2	2.4	5.1	4.2	10	S
41	429600	4406600	5.2	0.2	6.6	74.7	0.8	1.9	27.0	25.2	4	S
42	429500	4407650	5.7	0.1	9.0	61.9	0.8	1.0	13.5	16.4	7	S
43	430700	4407575	5.3	0.1	6.7	68.8	0.6	0.9	21.4	19.3	6	S
44	428600	4410500	5.7	0.1	8.1	60.9	0.6	0.9	10.1	20.1	7	LS
45	429450	4409625	5.3	0.2	7.4	62.0	1.2	1.2	25.4	24.2	3	S
46	430525	4409700	5.5	0.5	8.2	52.3	0.8	0.7	17.1	19.3	6	S
47	430725	4410450	5.2	0.2	9.1	71.1	0.9	1.1	26.9	27.8	5	S
48	429425	4410675	5.9	0.2	11.8	48.9	0.6	0.6	13.4	18.5	11	LS
49	427200	4400850	6.1	0.1	11.4	61.0	1.3	1.1	18.5	13.7	11	LS
50	428400	4401750	5.7	0.2	11.6	31.8	0.8	0.9	18.1	21.2	11	LS
51	429550	4402700	4.6	0.1	8.3	53.4	1.0	0.8	5.5	7.8	6	S
52	428400	4403525	5.5	0.1	5.9	49.8	0.8	0.4	15.5	14.6	4	S
53	428050	4400250	5.9	0.1	6.1	69.1	0.6	0.5	14.0	15.2	5	S
54	434400	4402350	6.0	0.3	5.8	47.8	0.5	0.2	8.1	7.5	4	S
55	434850	4401325	6.3	1.3	5.3	43.6	0.7	0.6	17.8	16.3	2	S
56	435475	4400500	6.2	2.9	7.2	61.8	0.9	0.5	12.3	13.2	5	S
57	443300	4406650	5.6	0.2	6.1	56.8	1.0	0.8	22.4	23.5	4	S
58	443450	4405500	6.5	0.3	6.5	76.6	0.5	1.8	11.1	12.1	6	S
59	444500	4404575	4.8	0.2	5.9	62.9	0.7	1.5	21.6	19.4	4	S
60	445600	4404400	5.9	0.2	12.2	51.9	0.6	1.4	24.9	25.7	11	LS
61	445690	4403450	5.4	1.0	7.1	48.4	0.6	1.0	16.4	14.2	5	S
62	433000	4399000	6.8	0.3	6.7	65.6	0.5	1.8	17.1	16.5	5	S
63	432300	4397800	4.8	0.3	5.5	52.0	0.8	1.6	23.0	20.9	4	S
64	431600	4394500	6.1	1.6	5.4	74.8	0.5	1.5	12.5	12.3	5	S
65	432000	4393000	5.4	1.3	5.1	62.2	0.9	0.8	26.4	19.7	2	S
66	431500	4391900	5.9	0.1	5.3	74.6	0.5	0.8	23.6	22.8	3	S
67	432750	4392800	5.2	0.1	4.9	84.2	1.5	1.3	25.0	25.7	2	S
68	429200	4384750	5.4	0.1	5.1	79.9	1.0	1.3	22.2	20.4	3	S
69	428600	4384200	5.5	1.5	4.8	89.5	0.6	0.7	19.9	17.2	2	S
70	427650	4382800	6.2	0.2	5.4	80.7	0.7	0.6	14.6	13.1	5	S
71	428300	4385500	5.4	0.2	6.0	102.5	0.4	0.6	13.0	14.2	5	S
72	457500	4401600	6.0	0.1	6.2	100.2	2.6	0.5	10.3	9.8	6	S

Table 1. Contd.

73	457600	4402400	6.1	1.0	23.1	35.2	2.1	0.5	9.4	10.1	25	SCL
74	456450	4401500	5.9	0.2	5.8	11.9	0.8	1.5	11.9	12.4	5	S
75	456525	4402575	5.5	0.3	10.9	22.3	0.8	0.7	13.8	12.7	11	LS
76	431150	4368600	5.5	0.8	8.3	12.2	0.6	0.9	13.4	14.3	7	S
77	434250	4369925	5.6	1.1	4.2	13.8	0.8	0.6	19.9	21.2	4	S
78	428100	4369400	6.8	1.2	5.3	12.2	0.4	0.1	13.1	14.7	6	S
79	428000	4372000	6.3	1.0	5.5	18.0	0.9	0.6	10.3	8.9	6	S
80	445200	4371800	6.8	0.2	6.1	18.0	0.5	0.8	10.8	9.5	7	S
81	444100	4372200	5.0	0.2	5.2	19.1	1.0	0.6	26.0	24.3	5	S
82	442900	4372400	5.8	1.5	4.9	18.9	0.3	1.8	18.4	17.1	5	S
83	440250	4372150	7.6	11.0	20.9	15.8	1.1	0.9	3.5	2.9	20	SL
84	439200	4372450	7.6	11.4	20.4	15.7	1.6	1.1	3.4	3.1	18	SL
85	438300	4371850	7.4	35.6	23.8	14.6	1.3	1.4	3.6	3.4	23	SCL
86	439400	4373000	7.8	36.6	19.9	12.6	1.2	1.4	3.1	2.8	19	SL
87	447650	4372700	7.7	28.0	20.8	15.8	1.8	1.0	3.2	3.3	21	SCL
88	449100	4373000	7.5	29.4	17.4	32.5	0.9	1.6	3.9	3.7	16	LS
89	450200	4373550	7.6	41.8	18.7	19.1	1.6	1.4	3.6	3.1	19	LS
90	449650	4374450	7.7	33.9	21.3	14.2	1.2	1.2	3.9	3.8	23	SCL
91	450550	4374825	7.4	30.5	15.1	14.3	0.9	1.3	3.6	2.9	14	LS
92	451400	4376300	7.3	28.8	19.6	13.1	0.5	1.4	3.4	3.2	18	LS
93	452950	4374950	7.2	18.0	11.4	13.6	0.6	1.4	3.5	3.8	10	S
94	454450	4375200	7.6	22.1	11.5	15.0	0.5	1.6	3.1	3.4	10	S
95	454600	4376050	7.6	23.4	23.1	15.6	0.8	1.4	3.4	2.8	21	SCL
96	455350	4376100	7.8	37.1	14.4	14.5	0.5	1.2	2.4	2.3	13	LS
97	456400	4375850	7.7	19.9	11.8	14.8	0.4	1.7	2.9	2.7	10	S
98	456650	4377500	7.6	19.6	22.1	13.6	0.3	0.6	3.1	3.2	24	SCL
99	456850	4376100	7.8	21.9	11.1	14.7	0.2	0.5	2.0	2.1	9	S
100	454800	4376200	7.4	31.1	15.2	17.4	0.3	1.4	2.5	2.7	17	SL
101	453750	4376300	7.5	34.1	11.7	15.9	0.5	1.2	2.5	2.3	11	LS
102	458900	4376250	7.9	31.3	26.4	19.9	0.6	0.8	2.9	2.4	28	SCL
103	460875	4376400	7.4	8.9	17.6	15.8	0.7	0.8	2.8	3.1	18	SL
104	460925	4376775	7.3	14.9	15.9	20.8	0.7	0.2	2.1	1.9	15	LS
105	461150	4376400	7.5	8.9	30.6	28.9	1.0	0.2	2.4	1.9	33	SCL
106	461950	4376650	7.7	15.9	31.1	18.4	0.8	1.4	2.9	3.1	33	SCL
107	462250	4376700	7.4	8.1	22.6	16.3	1.9	1.1	2.5	2.4	34	SCL
108	463200	4377100	8.1	14.4	15.3	15.0	0.8	0.8	2.6	2.8	19	SL
109	463900	4377600	7.7	8.3	22.5	13.6	1.2	0.7	2.1	1.7	26	SCL

Table 1. Contd.

110	464750	4377725	7.5	19.9	18.7	19.1	0.9	0.4	2.4	3.2	21	SCL
111	465100	4378200	7.2	26.5	9.0	20.8	1.6	0.5	1.9	1.6	7	S
112	465900	4378400	7.2	25.7	8.9	18.4	1.4	0.9	1.1	1.3	8	S
113	465000	4379000	6.2	0.2	19.0	18.9	1.5	1.9	15.0	14.2	19	SL
114	466150	4378700	6.8	0.2	26.4	19.8	1.0	1.2	10.1	8.9	30	SCL

chemical acids should be applied (Kacar and Katkat, 2010). Iron (Fe) varied from 1-27 ppm in the research area, with an average of 8.239 ppm(Table 2, Figures 2 and 3). It was determined to be at low levels (Fe ≤ 2.5) in 28.9% of the samples, at adequate levels (2.5-4.5) in 28.9%, and at high levels (Fe >4.5) in 42.2% (Table 1) (Eyupoglu et al., 1996). The usefulness of iron in calcareous soils is reduced by the concentration of HCO_3^{-1} (Bloom and Inskeep, 1988). In addition, the effect of high pH is more conspicuous. Due to high pH (pH>6.5), Fe cannot be received at 58% of the soils (Table 1) (Kalbasi et al., 1988; Kacar and Katkat, 2010). In 33.33% of the soils, in which lime ($CaCO_3$ > 15%) is high, it will not be possible to intake the iron. In return, the tomato highly reacts to iron deficiency. Therefore, iron deficiency should be observed in those areas, and fertilization should be done through the leaf. On the other hand, although statistically not significant, there exists a negative relationship between Fe and Zn, as well as % clay content (Table 3). The solution is to lower the pH level (Kacar, 2012; Güneş et al., 2013).

Manganese (Mn) varied from 1.2 to 27.8 ppm, with an average of 8.2 ppm (Table 2; Figures 2 and 3). In addition, a statistically non-significant negative relationship between Mn and Zn, along with clay % was determined (Table 3). While useful manganese increased at a lower pH level, it decreased at higher pH levels (Table 1; Figure 3). Mn level was found to be sufficient (< 10 ppm) in 66.67% of the samples, high (10-20 ppm) in 21.93% and very high (> 20 ppm) in 11.40% in research (Table 1) (Kacar, 2012; Güneş et al., 2013). In 65% of the soils in Turkey, Mn varies between 15-50 ppm (Eyupoğlu et al., 1996).

According to the results, Mn level is considered sufficient (Martens and Westermann, 1991). 31.57% of the research soil is calcareous alkaline, and 30.70% is sandy-acidic. However, in the lime-alkaline soil (pH>7; $CaCO_3$ > 15%) Mn is difficult to absorb, because the formed manganese oxide (MnO) and manganese hydroxides [$Mn(OH)_2$] prevent absorption (McKenzie, 1989). In sandy acidic soil, Mn undergoes a washing process due to the lack of bonding surface despite high solubility, and it cannot be taken at sufficient levels. Therefore, there may be Mn deficiency in plants grown in sandy-acidic soils and in calcareous-alkaline soils (Kacar and Katkat, 2010). Furthermore, high phosphorus has a negative effect on Mn intake and its transport in plants (Taban et al., 1995; Kacar and Katkat, 2010). As a result, in 62.70% of the soils of the research area, high phosphorus (P), pH and lime conditions should be taken into account and the pH must be adjusted (Karaman et al., 2012).

Zinc (Zn) varied from 0.2 to 2.8 ppm in the research area, with an average value of 0.9 ppm (Table 2, Figures 2 and 3). There was no statistically significant relationship between Zn and other parameters (Table 3). According to these values, it was determined to be at sufficient and high levels in 23.68% of research area soils, and at low and very low levels in 76.32% of the soils (Table 1; Figures 2 and 3) (Kaplan et al., 1997; Kacar and Katkat, 2010; Karaman et al., 2012). Marschner (1991) stated that the amount of exchangeable zinc varied between 0.1 and 2.0 ppm depending on soil properties (Hacısalihooğlu et al., 2004).

This information confirms the results of the research. There is a difference between plants in terms of zinc intake. For example, tomatoes receive only 30% of the given zinc. Due to its being at low soil temperature, high pH and high phosphorus contents also reduce Zn intake (Hacısalihooğlu et al., 2004). As soil pH increases, variable Zn decreases (Kacar and Katkat, 2010). The information provided confirms the research findings. Therefore, while applying Zn in the research area, phosphorus and pH must be taken into consideration, and the pH must be absolutely calibrated (Güneş et al., 2013).

Zinc should be given as needed. In fact, it should be applied through the leaf, especially in areas where pH is high. Because of the high pH and high calcareous conditions; its solubility decreases and it cannot be taken by forming compounds such as zinc carbonate ($ZnCO_3$) and zinc hydroxide [$Zn(OH)_2$] with carbonates (Karaman et al., 2012).

Copper (Cu) was varied between 0.1 and 2.6 ppm in the samples, and the mean value was determined to be 1.06 ppm (Table 2, Figures 2

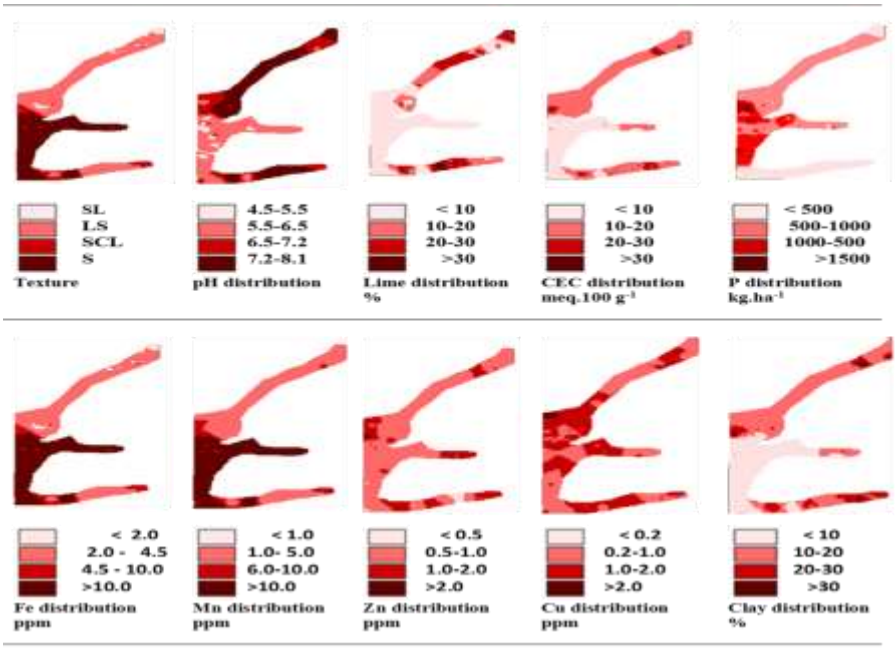

Figure 2. Mappings according to levels of research findings.

Figure 3. Analysis results of the soils samples according to coordinates.

Table 2. Descriptive statistics.

*Paramet.	N. Stat.	Range Stat.	Min. Stat.	Maxi. Stat.	Mean Stat.	Std. Stat.	Variance Stat.	Skewness		Kurtosıs	
								Statist	Std.	Statist	Std.
pH	114	3.5	4.6	8.1	6.756	0.9373	8.7859	-0.506	0.226	-1.14	0.449
$CaCO_3$	114	41.7	0.1	41.8	10.95	13.69101	1874.44	0.903	0.226	0.733	0.449
CEC	114	27.4	4.2	31.6	13.65	6.93345	480.73	0.697	0.226	0.119	0.449
Fe	114	26	1	27	8.239	7.78484	606.04	1.05	0.226	0.237	0.499
Mn	114	26.6	1.2	27.8	8.217	7.61804	580.34	0.973	0.226	0.414	0.449
Zn	114	2.6	0.2	2.8	0.911	0.48477	2.35	1.792	0.226	3.779	0.499
Cu	114	2.4	0.2	2.6	1.066	0.53511	2.8634	0.807	0.226	0.291	0.499
P	114	204.2	10.5	214.7	41.68	33.09612	109535	2.304	0.226	7.564	0.449
Clay	114	3.2	0.2	3.4	1.31	0.81646	6.6661	0.807	0.226	0.02	0.499

*pH (1:2.5); $CaCO_3$ (%); CEC (meq.100 g^{-1}); Fe (ppm); Mn (ppm); Zn (ppm); Cu (ppm); P (kg.ha^{-1}); Clay (%).

Table 3. Correlations between parameters.

Parameters	pH (1:2.5)	$CaCO_3$ (%)	CEC (meq.100 g^{-1})	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	P (kg.ha^{-1})
$CaCO_3$ (%)	0.672							
CEC (meq.100 g^{-1})	0.613	0.429						
Fe (ppm)	-0.847	-0.566	-0.605					
Mn (ppm)	-0.872	-0.585	-0.608	0.975				
Zn (ppm)	0.028	0.012	0.402	-0.080	-0.095			
Cu (ppm)	0.001	-0.061	0.023	0.013	0.005	0.106		
P (kg.ha^{-1})	-0.369	-0.431	-0.203	0.312	0.315	0.237	0.079	
Clay(%)	0.613	0.396	0.977	-0.599	-0.603	0.389	-0.028	-0.217

and 3). Cu was found to be at inadequate levels (≤0.2) in 3.5%, and adequate levels in 96.5% of the research area (Table 1) (Eyupoğlu et al., 1996; Karaman et al., 2012). This depends on the copper-based pesticides used. Kochian (1991) reported that 98% of Cu in the soil solution forms a complex with organic compounds and therefore it is immobilized (Kacar and Katkat, 2010). In addition, Haldar and Mandal (1981) reported that Zn^{++} and Cu^{++}, which are present in excessive amounts in the soil, adversely affect their intake by plants (Kacar and Katkat, 2010). No application proposal was needed because it was found to be sufficient in almost all soil samples (Hacısalihooğlu et al., 2004).

In the survey, clay was detected only in 20 samples (clay: 20-35%) (Figures 2 and 3). These fields are defined as SCL (Güneş et al., 2013). No clay-textures (clay >35%) were detected in any of the other units. In this respect, the research area was determined to be suitable for tomato production (Brady and Weil, 2008).

Conclusion

The main problem in the research area is that there may be problems related to the intake of P, Zn, Mn and Fe depending on the level of pH and lime. According to the research results, texture containing sand, loam and clay combinations except for 100% clay are suitable for tomatoes. Whereas at pH 6.5 and above 10% of lime; 1-2 ton.ha^{-1} of elemental powder sulfur or organic acids should be used and where pH is below 6.0, $CaCO_3$ or $Ca(OH)_2$ should be used depending on the pH level. Thus, the pH will be calibrated and antagonistic relationship between P, Zn, Mn and Fe will be prevented. Especially where the lime is above 10%, application of P is given locally without mixing to the soil, while Zn, Mn and Fe should be fed to the plants from the leaves.

CEC was under 15 meq.100 g^{-1} in 63.17% of the research areas. For these areas, 20-30 tons.ha^{-1} leonardite should be used to increase the CEC values.

Cu, Mn and Fe was enough with higher percentages (96.5, 88.6 and 71.1%) of the soil samples, respectively. Zn was found to be low and very low in 76.3% of the samples. Because there is a more important antagonistic relationship between the Zn with pH, % $CaCO_3$ and P, Zn is found to be low; so the application must be made from the leaves.

Higher Mn is related to rich mangan soils of Turkey,

while higher Cu is related to the copper element in the compositions of pesticides. The state of Fe also depends on high iron application.

Therefore, when Cu and Mn are not given, Fe should be applied to the leaf.

If the recommendations are followed, the pH and CEC in the research area will be adjusted and P and Zn intake will be easier. In addition, the nutrition problem of tomatoes will be eliminated and the yield will be increased.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

REFERENCES

Akdemir B, Kayişoğlu B, Kavdır I (1994). MSTAT Statistical package program usage book. Trakya University of Tekirdag Agricultural Faculty, Publication No: 203:189.

Arya K, Roy K (2009). Manganese induced changes in growth chorophyll contet and antioxidants activity in seedlings of broad bean (Vici faba L.). Journal Environment Biology 32:707-711.

Bloom PR, Inskeep WP (1988). Factors affecting bicarbonate chemistry and iron chlorosis in soils. Journal Plant Nutrition 9:215-228.

Bouyoucos GJ (1962). Hydrometer Method Improved For Making Particle Size Analysis Of Soil, Agronomy Journal 54(5).

Brady NC, Weil RR (2008). The natüre and prospertiesof soils. 14th ed., Upper Saddle River, NJ. pp. 9990,ISBN 13-978-0-13-227938-3,prenice Hall.

Eyüpoğlu F, Kurucu N, Talaz S (1996). A plant of Turkey's land some microelements plant-available (Fe, Cu, Zn, Mn). S. 1-72. Soil Fertilizer Research Institute general publication no. 127, serial no. R-133, Ankara.

FAOSTAT (2018). Food and Agriculture Organization Statistics, data 2002, (http://www.fao.org/faostat/en/#data/QC).

Guntekin E, Uner B, Karakuş B (2009). Chemical composition of tomato (Solanum lycopersicum) stalk and suitability in the particleboard production. Journal Environment Biology 30(5):731-734.

Güneş A, Alpaslan M, Inal A (2013). Plant Nutrition and Fertilization, Ankara University Faculty of Agriculture, Publication no: 1581:579.

Hacısalihoğlu G, Öztürk L, Çakmak I, Welch RM, Kochıan L (2004). Genotypic variation in common been in response to zinc deficiency in calcareous soil. Plant and soil 259:71-83.

Haldar M, Mandal LN (1981). Effect of P and Zn on the growth and P, Zn, Cu Fe and Mn nutrition of rice. Plant and Soil 59:415-420.

Jackson ML (1973). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

Kacar B, Katkat AV (2010). Plant Nutrition. Nobel Publication No. 849, 5th Edition.

Kacar B (2012). Soil Analysis. Nobel Publications, Publication no: 484, 3rd Edition, Ankara 464 p.

Kalbasi M, Filsoof F, Rezai-Nejad Y (1983). Effect of sülfür treatments on yield and uptake of Fe, Zn and by corn, sorghum and soyabeans. Journal Plant Nutrition 11(6-11):1353-1360.

Kaplan M, Aksoy T, Sönmez S, Orman Ş (1997). An Investigation of Zinc Nutrition Status in Greenhouse Tomato and Cucumber Cultivation in Western Mediterranean Region. 1st National Zinc Congress (Agriculture, Food and Health), 12-16 May, Eskişehir pp. 167-174.

Karaman MR, Brohi AR, Muftuoglu NM, Oztas T, Rich M (2012). Sustainable Soil efficiency, Koyulhisar Chamber of Agriculture Culture publications No: 1, 3rd Edition.

Kocihan LV (1991). Mechanisms of micronutrient uptake and translocation in plants. In. Mictonutrients in Agriculture, SSSA Book Series (4):229-296.

Lindsay WH, Norvell WA (1978). Development of DTPA soil test for Zn, Fe, Mn and Cu. Soil Science Society of America Journal 42:420-428.

Martens DC, Westermann DT (1991). Fertilizer applications for correcting micronutrient deficiencies. In: Micronutrients in Agriculture (2nd Edition). SSSA Book Series, SSSA, 677 S. Segoe Rd., Madison, WI 53711. 4:549-592.

Mandal S, Verma BC, Ramkrushna GI, Singh RK, Rajkhowa DJ (2105). Characterization of biochar obtained from weeds and its effect on soil properties of North eastern region of India. Journal Environment Biology 36:499-505.

McKenzie RM (1989). Maganese oxide and hidroxides. P. 439-466. In: Miner-als in soil Environments. (J. B. Dixon and S. B. Weed, eds.). 2nd ed. SSSA Madison, WI.

Marschner H (1991). Root-induced changes in the availability of micronutrients in the rihizospher. In: Plant Roots. The Hidden Half (Y. Waisel, A. Esheland K. Kafkafi eds) pp. 503-528.

Moreno CS, Ancos B, Plaza L, Martinez PE, Cano MP (2008). Nutritional Characterization of Tomato Juices, In: Tomato and Tomato Products Nutritional, Medicinal and Therapeutic Properties. Predy, V.R. Watson, R.R. (eds), Science Publisher, 664, USA.

Olsen RV, Cole CV, Watanable FS, Dean LA (1954). Estimation of Available Phosphorous in Soil by Extraction with Sodium Bicarbonate, U.S.D.A. Circ. 939, Washington.

Pendey SK, Chandra KK (2013). Impact of ıntegrated nutrient management on tomato yield under farmers field conditions. Journal Environment Biology 34:1047-1051.

Petro-Turza M (1987). Flavor of Tomato and Tomato Products. Food Review International 2(3):309-351.

Rathore N, Gupta RK, Singh Y, Singh B (2017). Determining critical value of soil Olsen P for dry direct seeded rice (Oryaza sativa) in a greenhouse study in Northwestern India. Journal Environment Biology 38:623-629.

Sun B, Paul D, Hallett SC, Timand JD, David WH (2011). Dustribution of soil carbon and microbial biomass in arable soils under different tillage regimes. Plant Soil 338:17-25.

Taban S, Alpaslan M, Turan C (1995). Effect of phosphorus and manganese lentil plant growth on phosphorus and manganese scales in increasing quantities. Tropical. Journal of Agriculture and Fosrestry 19:39-43.

Turkey Statistical Institute (TSI) (2017). Crop production statistics, data vegetables (tomatoes), https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr.

Vol. 13(50), pp. 2818-2825, 13 December, 2018
DOI: 10.5897/AJAR2017.12490
Article Number: 03A78BD59502
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Factors influencing commercialization of sweet potato in Mosocho Subcounty, Kenya

Winnie Kemunto Mageto* and Kamau Gathiaka

School of Economics, University of Nairobi, University Way, Nairobi, Kenya.

Received 2 June, 2016; Accepted 10 October, 2017

Sweet potato is a traditional crop grown in most parts of Kenya. In Nyanza Region, Kisii County and Mosocho sub-county in particular are major producers of the crop. However, only less than half of the produce is marketed and the growers are largely poverty stricken. This paper investigates why so little of the produce is marketed. Using primary data collected from a survey of 108 farmers in Mosocho, the study estimates a logit model to explain the factors that influence commercialization of sweet potatoes in the area. Results show that poor market information for the many farmers who are not members of any cooperative society, limited non-farm incomes, and urbanization are the major factors constraining commercialization of the root crop. Interventions that promote cooperatives and rural industrialization could go a long way in boosting trade in sweet potatoes.

Key words: Sweet potato, commercialization, smallholder farms, logit model, Mosocho, Kenya.

INTRODUCTION

Sweet potato (*Ipomoea batatas*) is a root crop within the morning glory family (Colvolvulaceae). Its origin is thought to be Latin America and it is believed to have been brought to Africa by slave traders. The exact date of its arrival is unknown. The crop has, however, been in the food system in Africa for a long time, and it is widely considered as an indigenous or traditional crop in the region.

Sweet potato is ranked fifth among the most important food crops (Scott et al., 1999). It is rich in energy, carbohydrates, fiber, minerals (especially potassium) and vitamins (especially vitamin A). A serving of 100 g (about half a cup) of boiled sweet potato (especially the orange fleshed type) supplies 50% of vitamin A daily requirement (Hagenimana and Low, 2000).

Potato is a promising plant remedy for vitamin A deficiency and Uganda has been trying this option. The International Potato Research Center has developed sweet potato varieties richer in beta carotenes that the body uses to synthesize Vitamin A and with high dry matter content (Bachou and Labadarios, 2002). This is an example of bio-fortified crop varieties with increased mineral and vitamin content that can raise nutritional standards in people.

According to FAOSTAT data, 80 to 85% of the total world production of sweet potatoes is from Asia with

*Corresponding author. E-mail: magetowinnie@gmail.com.

China on the lead (Bruinsma, 2009). In 2010, Asia produced about 90 million metric tonnes of the crop while Africa produced about 15 million metric tonnes. In Africa, Uganda is the leading producer of the crop followed by Tanzania (Bruinsma, 2009). The report also shows that in 2010, Uganda produced about 2.75 million metric tonnes of the crop compared to Kenya's 950,000 metric tonnes.

In Kenya, sweet potato is grown in several areas including Siaya, Homa Bay and Kisii in Nyanza region; Kiambu and Kirinyaga in Central region; Meru in Eastern region; Bungoma, Kakamega, Busia in Western region; and Shimba Hills in the Coast region. Notably, 60% of the households in these areas are poor (Qaim, 1999). Woolfe (1992) observes that the potential of the crop to address issues of income generation, nutritional deficit and food security is yet to be fully realized in less developed countries. The marketing and value addition of the crop are poor, yet these are measures that could uplift the wellbeing of the farmers.

The local as well as the export market for sweet potatoes is on the increase. At the local level, perceptions towards traditional foods are improving. The consumption of sweet potatoes as well as cassava, arrow roots and yams is increasing in both rural and urban areas. Both the affluent and the poor are increasing their consumption of the root crop. Crops that were once thought to be 'poor man's crops' are slowly gaining popularity due to their health benefits. In urban areas, sweet potato is increasingly becoming an alternative breakfast food while in rural areas it is variously used to prepare meals and in baking.

The crop is also used to feed animals. Sweet potato root and vines are feed for poultry, rabbits, pigs, cattle, sheep and goats. In some parts of Papua New Guinea, farmers slice up the sweet potatoes and mix them with vines to improve digestion. In Philippines, boiled sweet potatoes are used to fatten pigs. In poultry farming, sweet potatoes improve the dressing and can substitute up to 50% of maize (Loebenstein, 2009). Its dual nature as a food as well as a feed makes sweet potato an attractive crop in areas where landholding is declining.

In industries the starch obtained from sweet potato is used to manufacture sweeteners, and as a stabilizer and thickener in the textile industries. Sweet potato can be harvested in bits. This flexibility affords households a continuous supply of the crop, and income in case of marketed harvests. To improve the marketing of the crop, Andrade et al. (2009) observe that there is an urgent need for capacity building on postharvest management, better storage facilities, and to designate specific areas in markets as display points for sweet potatoes to easily connect sellers to buyers.

Sweet potato crop has the potential to address poverty, wealth creation, diversification of smallholder agriculture and food security. In recognition of its nutritional and potential benefits the United Nations declared 2008 as the year of sweet potato (Joel et al., 2009).

Nevertheless, sweet potato has been an orphan crop. There are only a few empirical studies on the crop worldwide. On commercialization of the crop, there are even fewer studies. It is against this background that this paper explores the determinants of sweet potato commercialization focusing on Mosocho Sub-county of Kisii County. Mosocho is a leading producer of sweet potatoes in Kisii. Sweet potatoes from Kisii are particularly appealing and tasty. They are a favorite in the Kenyan market.

LITERATURE REVIEW

Bouis and Haddad (1990) define commercialization as the total percentage value of output that is marketed. However, according to Pingali (1997) agricultural commercialization is more than just marketing agricultural products. Agricultural commercialization is attained when input use decisions and product choice are made on profit maximization basis. Von Braun and Kennedy (1994) add that agricultural commercialization entails an increase in market transactions in order to gain the benefits from commercialization.

Commercialization of agriculture has the potential to reduce poverty and food insecurity. To reduce poverty through commercializing agricultural produce, farmers must consider adding value to what they sell (Ayako & Hernandez, 2017).

Sweet potatoes are largely grown by smallholder farmers. According to Leavy and Poulton (2007), small scale farmers fall into two categories: non-commercial farmers and commercial farmers. The non-commercial farmers mainly practice subsistence production but they may sell a portion of their produce to the market. Their livelihoods are not drawn from agriculture. The commercial small scale farmers are largely market-oriented. They produce agricultural outputs primarily for the market but the output may also meet household consumption. This category of farmers tends to specialize on highly valued agricultural activities. The small-investor farmer is the "emerging" commercial farmer. According to Gebreselassie and Kay (2007), the small-investor farmer includes the educated and urban based individuals who engage in agriculture exclusively on commercial basis. All the produce of a small-investor is marketed.

Pingali and Rosengrant (1995) identify three levels of market participation and which are elaborated by Leavy and Poulton (2007). They are the subsistence system, semi-commercial system and fully commercialized system. The different levels are differentiated on the basis of the farm household's objective in production, its source of inputs, product mix and income sources. Table 1 shows these classifications and the associated

Table 1. Level of market participation and farm-household characteristics.

Level of market participation	Farm-household's objective	Source of inputs	Product mix	Household income sources
Subsistence agriculture	Food self-sufficiency	Generated by the household	Wide range of produce	Mostly from agriculture
Semi-commercial	Surplus generation	Mix of traded and non-traded inputs	Semi-specialized	Both agriculture and other sources which are not agriculture-based
Fully commercial	Profit maximization	Highly tradable inputs	Highly specialized	Predominantly non-agricultural

Source: Pingali and Rosegrant (1995).

characteristics of farm-households.

Von Braun and Kennedy (1994) specify three modes of commercialization indices at household level. These include commercialization of the rural economy, commercialization of input and output, and the degree of a household's involvement in the money or cash economy. The index of commercialization of input and output is the ratio of input acquired from market or output sold to the market to the total value of agricultural produce. The index of household involvement in money/cash economy is the proportion of value of services and goods acquired in monetary terms to total household earning (von Braun and Kennedy, 1994). Govereh et al. (1999) use the ratio of the gross value of all crop sales by a household per year to the gross value of all crops produced within the year as the household commercialization index (HCI). A major weakness in this ratio is that it excludes livestock output which could be an important factor in some farming systems. Bernard et al. (2007) measure household commercialization variously by sales to income ratio, sales-to-output ratio, income diversification, level of specialization in agricultural production, and net or absolute market position of a household either as a net buyer, net seller or autarkic/self-sufficient.

According to Govereh et al. (1999), increased market participation is associated with rising farm productivity and income. They assume that commercialized farmers largely specialize on production of high value cash crops that yield high returns to labor and land. Timmer (1997) has similar views when he argues that agricultural commercialization is associated with benefits that include high level of specialization and production, and higher earnings from produce sales.

However, the benefits of commercialization depend on market efficiency. If markets are efficient, commercialization leads to separation of production from consumption (Bernard et al., 2007). Gebreselassie and Kay (2007) argue that even though greater involvement in output markets results in higher productivity which is an intermediate outcome, agricultural commercialization is a bridge through which small scale commercial farmers could achieve welfare goals.

At a micro level, distance to the market and output price (Omiti et al., 2009), farm size and the number of workers employed are crucial determinants of marketed output or sales volume in a smallholder farm. Balint (2004) in a study of the effect of institutional factors on agricultural sales in Romania finds that farm size, production costs, farming assets, transaction costs and cooperation among farmers significantly contribute to agricultural sales volume. Lerman (2004) find similar results in a study of farm produce marketing among small scale farmers in transitional economies. Martey et al. (2012) in a Tobit regression of commercialization of agriculture in Ghana find farm size, output price, and households' access to extension service, market information and distance to market to be important determinants.

Baisa (2009), in a research of why some smallholder farmers in Ethiopia sell more output than others, used a multivariate linear regression analysis to identify the relationship between the gross value of all crops sold and the socio-economic characteristics of households. The study found that farm and household characteristics are the main determinants of the phenomenon. Other determinants of commercialization in value terms according to this study include market information, access to credit and access to transport. In a similar study of determinants of commercialization of smallholder tomato and pineapple farms in Ghana, Asuming-Brempong et al. (2013) found that the key determinants of commercialization among tomato farmers are land and labor productivity while the main determinants of commercialization among pineapple smallholder farmers are land productivity and savings. The study favors commercialization arguing that commercialization comes with several benefits that include higher household incomes and improvement in household food security.

Using the Tanzanian National Panel Survey data compiled by FAO, Nobeji (2015) analyzed the determinants of market participation by smallholder rice farmers in the five major rice producing regions of Tanzania. Quantitative analysis involving estimation of

Weighted Least Squares (WLS) and Tobit regression to establish factors affecting volume of sales and determinants of market participation found that household socio-demographic characteristics of smallholder rice farmers influence production and market participation. Results of the Tobit regression model indicate that household consumption, area cultivated, livestock owned and location significantly influence volume of sales and market participation while nonfarm income, Mbeya and Tabora regions significantly but negatively influence market participation. Further, low rice production, underdeveloped transport infrastructure and lack of reliable markets closer to higher rice producing regions and inadequate access and use of improved seeds and input were found to be the main problems associated with smallholder farmers in the study area.

In a research carried out by Kirui and Njiraini (2013) on determinants of agricultural commercialization among the rural poor in Kenya using the Tobit regression, they found that farmer-specific characteristics, farm-specific and capital endowment variables influence the commercialization process. Female farmers are constrained from market participation; however, collective action initiatives (farmer groups) as well as use of information and communication technology (ICT) tools (mobile phones) significantly and positively influence their commercialization.

Omiti et al. (2009) use truncated regression to study factors influencing the intensity of market participation between rural and peri-urban smallholder farmers in Kenya. Results show that farmers in peri-urban areas sell higher proportions of their output compared to their counterparts in rural areas. Distance from the farm to sale point is a major constraint to the intensity of market participation. Better output price and market information are key incentives for increased sales.

The various studies show that different constraints limit smallholder farmers' participation in the market. Thus, crop or area specific research is required to identify the specific commercialization constraints that can inform specific policy.

METHODOLOGY

To determine the level of sweet potato commercialization in a household, the household commercialization index (HCI) is used as in Govereh et al. (1999). The index is a ratio of gross value of crop sales by a household in a period to gross value of crop output within the same period expressed as a percentage.

$$HCI = \left[\frac{(\text{Gross value of sweet potatoes sold in a period})}{(\text{Gross value of sweet potatoes produced in the period})}\right] \times 100$$

The commercialization index ranges between zero and one hundred percent. A value of one hundred percent signifies full commercialization while zero indicates pure subsistence production. The following model could capture the relationship between commercialization and its covariates.

$$HCI^* = X B + \varepsilon \quad (1)$$

where HCI^* is the household commercialization index, X is a vector of covariates and B is a vector of parameters. ε is an error term. The covariates include household characteristics, institutional factors and village characteristics.

Given that sweet potato farmers in the study area are small scale producers for both the market and household consumption on less than a hectare of land, it may be argued that a household with a HCI* of 50% or more is highly commercialized while a household with an index below 50% is lowly commercialized.

Thus, Equation 1 could be rewritten as a binary response index model of sweet potato commercialization with HCI = 1 if [HCI* ≥ 0.5] and HCI = 0 if [HCI* < 0.5]. Following Wooldridge (2002), the latent variable model in Equation 1 can be transformed into a response probability function.

$$HCI = 1\ [HCI^* \geq 0.5] \quad (2)$$

and

$$P\ (HCI=1|X) = P\ (HCI^* \geq 0.5|X) = G(XB) = p(X) \quad (3)$$

The function G maps the index HCI into the response probability. Assuming that the error term followed a standard logistic distribution, the estimated response probability function was to be a logit model. If the error term followed a standard normal distribution, the response probability function was to be a probit model. Since the results from estimating either model would not be much different, the study took the first option and estimated a logit model of the form:

$$\text{Logit } L_i = \ln [P_i/(1-P_i)] = X B + \varepsilon \quad (4)$$

The data used in the estimation were collected through face-to-face interviews with 108 farmers randomly picked from Mosocho sub-county with the help of Kenya National Bureau of Statistics household listing. Table 2 describes the variables used and their measurement.

RESULTS AND DISCUSSION

The results that follow were generated using STATA 12 software. Table 3 shows the summary statistics of the variables considered in the estimation of the logit model of sweet potato commercialization.

Table 3 shows that only less than half of farmers interviewed were commercialized. The farmers were middle-aged and of lower secondary. They farmed not far from market centres and majority of them belonged to a cooperative society that fed them with market information. Sweet potato farming in the study area was largely a family activity with men dominating. Despite the activity, household incomes were largely drawn from non-farm sources and loans. The average farm size was less than half a hectare and expansion of family units through leased land was not a readily available option. Table 4 shows the maximum likelihood estimates of the logit parameters, while Table 4 shows the corresponding

Table 2. Variable description and measurement.

Variable	Description	Measurement
HCI	Gross value of total sweet potato sales per week/Gross value of total sweet potato output per week	HCI=1 if highly commercialized, 0 otherwise
age	Age of household head	Number of years lived
agesq	Age of household head squared	Number of years lived squared
marsta	Marital status of the household head	1 if married, 0 if otherwise
gendr	Gender of the household head	1 if male, 0 otherwise
educ	Highest level of education attained by household head	Number of years of formal education
educsq	Highest level of education attained by household head squared	Number of years squared
labrfrce	Adult equivalents in a household who are active in own farm activities	Number
famsize	Size of the farm owned by the farmer	Hectares
landaces	Whether household has hired land	1 if yes, 0 if otherwise
creditaces	Household access to credit	1 if a household took a loan in the last one year, 0 if otherwise
info	Whether household is a member to a cooperative Society	1 if yes, 0 if otherwise
distmkt	Distance from the farm to the nearest market	Kilometers
nonfinc	Proportion of non-farm annual income to total annual household income	Ratio of non-farm to farm income

Source: Authors.

Table 3. Summary statistics of the variables.

Variable	Mean	Std. dev.	Minimum	Maximum
hci	0.44	0.23	0.12	1
age	38	10.18	21	75
marsta	0.63	0.49	0	1
gendr	0.65	0.87	0	1
educ	9.69	2.97	5	16
educsq	102.75	58.95	25	256
labrfrce	3.54	2.07	1	13
famsize	0.46	0.38	0.13	2
landaces	0.46	0.50	0	1
creditaces	0.51	0.50	0	1
info	0.56	0.50	0	1
distmkt	3.86	2.81	0	15
nonfinc	0.56	0.50	0	1
No. of obs.		108		

Source: Authors computations from field data.

odds.

From Table 4, membership to a cooperative society substantially increased the log-odds of a household being highly commercialized. Indeed, Table 5 confirms that households being a member of a cooperative increased the odds in favor of commercialization by over 100%. Table 5 shows that a sweet potato farmers' decision to join a cooperative of any kind increased his probability of producing for the market by about 17%. Unfortunately, only about half of the sweet potato

Table 4. Logistic regression results of sweet potato commercialization.

hci_st	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
age	-0.17904	0.161793	-1.11	0.268	0.49615	0.138069
agesq	0.002669	0.001916	1.39	0.164	0.00109	0.006423
marsta	0.469901	0.552264	0.85	0.395	0.61252	1.552319
gendr	0.618256	0.537969	1.15	0.25	0.43614	1.672655
educ	-0.03703	0.540158	-0.07	0.945	1.09572	1.021658
educsq	0.006143	0.02699	0.23	0.82	0.04676	0.059041
labrfrce	0.166105	0.129724	1.28	0.2	0.08815	0.420359
landaces	-0.09233	0.513858	-0.18	0.857	1.09947	0.914811
credav	-0.12027	0.525375	-0.23	0.819	1.14998	0.909449
info	0.98397	0.542121	1.82	0.07	0.07857	2.046508
distmkt	0.182251	0.094776	1.92	0.054	0.00351	0.368008
nonfinc	1.553932	0.621906	2.5	0.012	0.33502	2.772844
_cons	-2.08404	4.086615	-0.51	0.61	10.0937	5.92558
Number of observations			108			
Iteration 4: log likelihood = -52.248483			-			
LR $chi^2(12)$= 23.12			P=0.0267			
Pseudo R^2			0.1812			

Source: Authors computations from field data.

Table 5. Odds ratios of sweet potato commercialization.

hci_st	Odds ratio	Std. Err.	z	P>z	[95% Conf.	Interval]
age	0.836073	0.135271	-1.11	0.268	0.608871	1.148055
agesq	1.002672	0.001921	1.39	0.164	0.998915	1.006444
marsta	1.599836	0.883532	0.85	0.395	0.541985	4.722407
gendr	1.855688	0.998303	1.15	0.25	0.646525	5.326292
educ	0.963645	0.520521	-0.07	0.945	0.334298	2.777797
educsq	1.006161	0.027156	0.23	0.82	0.95432	1.060819
labrfrce	1.180697	0.153164	1.28	0.2	0.915625	1.522507
landaces	0.911803	0.468537	-0.18	0.857	0.333046	2.496304
credav	0.886684	0.465841	-0.23	0.819	0.316642	2.482953
info	2.675054	1.450203	1.82	0.07	0.924439	7.74082
distmkt	1.199915	0.113723	1.92	0.054	0.996499	1.444854
nonfinc	4.730032	2.941633	2.5	0.012	1.397968	16.00409
_cons	0.124427	0.508485	-0.51	0.61	4.13E-05	374.4958
Number of observations			108			
Iteration 4: log likelihood = -52.248483						
LR $chi^2(12)$=23.12			P=0.0267			
Pseudo R^2			0.1812			

Source: Authors computations from field data.

farmers in Mosocho were members of a cooperative society. This limited their information flow and capacity to produce for the market. Any policy that promotes the growth and development of cooperatives is likely to influence commercialization of sweet potatoes positively.

In spite of sweet potatoes being bulky, the distance from the farm to the market was found to influence commercialization of the crop positively. One kilometer increase in distance from the farm to the market increased the odds in favor of high commercialization by nearly 20%. Farmers close to a market centre had more economic options and only grew sweet potatoes as a side activity. The area near markets was actually densely populated with little land for cultivation.

However, farmers further away from a market had fewer economic opportunities, the population density was lower and the farmers had a higher likelihood of growing and selling more sweet potatoes. Table 5 shows that 1 km increase in distance from the farm to the market above the average of 3.9 km increased the probability of high commercialization by 3.2%.

This finding differed from that of Barrett (2008) and Omiti et al. (2009) that households far away from markets have low market orientation and commercialization. However, the finding was consistent with Jemimah et al. (2011) and Ruhangawebare (2010).

Non-farm income increased the odds in favor of high commercialization. A farming household that had nonfarm income was almost likely to be highly commercialized. Non-farm income increased the probability of high commercialization by an average farmer by nearly 26%. Households without non-farm income to purchase food items were more likely to consume more of the homegrown foodstuffs including sweet potatoes. This left them with little marketed output. Thus, opportunities for non-farm incomes such as rural and urban industrialization and non-farm businesses could have important implications on commercialization of sweet potatoes without endangering household food security. The finding is in line with Von Braun and Kennedy (1994), Jemimah et al. (2011), Ruhangawebare (2010) and Agwu and Ibeaabuchi (2011). These works find non-farm income to promote commercialization of farm output. The finding is, however, at variance with Barrett (2008), Martey et al. (2008) and Omiti et al. (2009) who argue the opposite.

That non-farm income increased the probability of high commercialization has wide implications on household nutrition too. Households without external sources of income were likely to be poorer, consume much of their farm output, and probably miss out on other nutritional foods available in the market. Rural industrialization and growth policies that offer opportunities for non-farm incomes have the likelihood to not only influence commercialization of farm output positively, but also household nutrition.

Farmers should be encouraged to diversify into non-farm and particularly non-agricultural activities. Alternative income sources have the likelihood to reduce dependency on homegrown crops for household consumption and to increase market participation.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Agwu NM, Ibeabuchi JO. (2011). Socio-economic determinants of commercialization among small holder farmers in Abia State, Nigeria. Greener Journal of Agricultural Sciences 2(8):392-397.

Andrade M, Barker I, Cole D, Fuentes S, Gruneberg W, Kapinga R, Low J (2009). Unleashing the potential of sweet potato in Sub-Saharan Africa: Current challenges and way forward. International Potato Center. http://www.sweetpotatoknowledge.org/files/unleashing-the-potential-of-sweetpotato-in-sub-saharan-africa-current-challenges-and-way-forward-2/

Asuming-Brempong S, John KA, Samuel A, Seth A (2013). Determinants of commercialization of smallholder tomato and pineapple farms in Ghana. American Journal of Experimental Agriculture 3(3):606.

Ayako E, Hernandez M (2017). Linking smallholder farmers to markets on extensive and intensive margins:Evidence from Nicaragua. Food Policy 73:34-44.

Bachou H, Labadarios D. (2002). The nutrition situation in Uganda. Nutrition 18(4):356-358.

Barrett C (2008). Smallholder market participation: Concepts and evidence from Eastern and Southern Africa. Food Policy 33:299-317

Baisa GA (2009). Commercialization of smallholder farming: determinants and welfare outcomes: a cross-sectional study in Enderta district, Tigrai, Ethiopia. Unpublished Master's thesis, Universitetet i Agder: University of Agder.

Bernard T, Gabre-Madhin E (2007). Smallholders' commercialization through cooperatives. International Food Policy Research Institute (IFPRI). Discussion paper 722.

Bouis HE, Haddad LJ (1990). Agricultural commercialization, nutrition, and the rural poor. Rienner. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.146.4066&rep=rep1&type=pdf

Bruinsma J (2009). The resource outlook to 2050: by how much do land, water and crop yields need to increase by 2050. Expert meeting on how to feed the world 205:24-26.

Gebreselassie S, Kay S (2007).Commercialization of Smallholder Agriculture in Selected Tef-Growing Areas of Ethiopia. Ethiopian Journal of Economics 16(1):55-86.

Govereh J, Jayne TS, Nyoro J (1999). Smallholder commercialization, interlinked markets and food crop productivity: Cross-country evidence in eastern and southern Africa. Michigan State University. Department of Agricultural Econ. Department Economics. Discussion paper 39.

Hagenimana V, Low J (2000). Potential of orange-fleshed sweet potatoes for raising vitamin A intake in Africa. Food Nutrition Bulletin 21(4):414-418.

Kirui OK, Njiraini GW (2013). Determinants of agricultural commercialization among the rural poor: The Role of ICT and Collective Action Initiatives and gender perspective in Kenya. In GI-Jahrestagung pp. 1747-1754.

Leavy J, Poulton C (2007). Commercialisations in agriculture. Ethiopian Journal of Economics 16(1):1-37.

Lerman Z (2004). Policies and institutions for commercialization of subsistence farms in transition countries. Journal of Asian Economics 15(3):461-479.

Loebenstein G, George T (2009). The sweetpotato. Springer Science & Business Media. https://www.springer.com/gp/book/9781402094743

Martey E, Al-Hassan RM, Kuwornu JK (2012). Commercialization of smallholder agriculture in Ghana: A Tobit regression analysis. African Journal of Agricultural Research 7(14): 2131-2141.

Nobeji SB, Nie F, Chen F (2015). An analysis of smallholder farmers' socio-economic determinants for input use: A case of major rice producing regions in Tanzania. RJOAS 2(38). https://cyberleninka.ru/article/v/an-analysis-of-smallholder-farmers-socio-economic-determinants-for-inputs-use-a-case-of-major-rice-producing-regions-in-tanzania

Joel N, Remans R, Karuti S, Fanzo JC (2009). ntegrating a broader notion of food security and gender empowerment into the African Green Revolution. Food Security, 1(3):351-360.

Jemimah N, Kaaria S, Chamunorwa A, Chiuri W (2011). Linking smallholder farmers to markets, gender and intra-household dynamics: Does the choice of commodity matter? The European Journal of Development Research 23(3):426-443.

Omiti J, Otieno D, Nyanamba T, McCullough E (2009). Factors

influencing the intensity of market participation by smallholder farmers: A case study of rural and peri-urban areas of Kenya. African Journal of Agricultural and Resource Economics 3(1):57-82.
Pingali PL, Rosegrant MW (1995). Agricultural commercialization and diversification: Processes and policies. Food Policy 20(3):171-185.
Qaim M (1999). The economic effects of genetically modified orphan commodities: projections for sweetpotato in Kenya. ISAAA. https://www.isaaa.org/resources/publications/briefs/13/download/isaaa-brief-13-1999.pdf
Ruhangawebare GK (2010). Factors affecting the level of commercialization among cattle keepers in the pastoral areas of Uganda. Unpublished Collaborative Masters Program in Agricultural and Applied Economics.
Scott GJ, Otieno J, Ferris SB, Muganga AK, Maldonado L (1999). Sweet potato in Ugandan food systems: Enhancing food security and alleviating poverty. CIP Program Report 1997-1998. 11 P. http://www.sweetpotatoknowledge.org/files/sweetpotato-in-uganda-food-systems-enhancing-food-security-and-alleviating-poverty/
Timmer CP (1997). Farmers and markets: The political economy of new paradigms. American Journal of Agricultural Economics 79(2):621-627.
Tudor M, Borbala B (2006). Off-farm employment and agricultural sales: Evidence from Romania. Post-Communist Economies 18(2):243-260.
Von Braun J, Kennedy E (eds). (1994). Agricultural commercialization, economic development, and nutrition. Johns Hopkins University Press. Baltimore.

Vol. 13(50), pp. 2826-2835, 13 December, 2018
DOI: 10.5897/AJAR2018.13592
Article Number: C40C16559504
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Quality of clonal plantlets of *Coffea canephora* Pierre ex A. Froehner produced using coffee husk in the substrate

Abraão Carlos Verdin Filho[1], Wagner Nunes Rodrigues[2*], Tafarel Victor Colodetti[2], Aldo Luís Mauri[1], Bruno Fardim Christo[2], Romário Gava Ferrão[1], Marcelo Antonio Tomaz[2], Marcone Comério[1], Saul de Andrade Júnior[2], Sheila Cristina Prucoli Posse[1], Lima Deleon Martins[2] and Sebastião Vinícius Batista Brinate[2]

[1]Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural (INCAPER), Marilândia, Espírito Santo, Brazil.
[2]Centro de Ciências Agrárias e Engenharias, Universidade Federal do Espírito Santo, Alegre, Espirito Santo, Brazil.

Received 2 October, 2018; Accepted 5 November, 2018

Coffee husk is a residue produced during the fruit processing and it is an excellent source of organic matter. It is an interesting alternative that can be used in the formation of the substrate to plantlet production, but the proportion to be recommended is still unknown. In this context, this experiment was conducted with the objective to study the growth, quality and gas exchange rates of clonal plantlets of Conilon coffee produced using plastic tubes, filled with substrate composed of different proportions of coffee husk to partially replace the commercial substrate. The experiment was conducted in a nursery, following a 3×6 factorial scheme in a completely randomized design; studying three genotypes of Conilon coffee and six proportions of coffee husk in the composition of the substrate for plantlets production from 0% to 100%. Overall, the results showed gains in growth and quality of the plantlets when coffee husk was added in the substrate but decrease in gas exchanges, especially over the net carbon assimilation. Considering the growth and quality, most detrimental effects started being observed with proportions above 38%. Different patterns of response were observed among genotypes, which must be taken into consideration for further researches to help define safety levels and a possible recommendation to use coffee husk in the substrate.

Key words: Asexual reproduction, Conilon coffee, plant nursery, biomass, Robusta coffee.

INTRODUCTION

Coffee crops have an undeniable importance for several countries worldwide and, among those, Brazil stands out as the world's largest producer of this commodity. Brazil grows plantations of both species of

*Corresponding author. E-mail: rodrigues@phytotechnics.com.

cultivated coffee: Arabica coffee (*Coffea arabica* L.) and Conilon coffee (*Coffea canephora* Pierre ex A. Froehner) (Conab, 2018); and this primary product has large historical and socio-economic value for the country, being an important economic source and creating several jobs along its productive chain.

The species *C. canephora* originated from tropical rainforests and has its reproduction majorly done by outcrossing, due to its mechanism of gametophytic self-incompatibility, which prevents self-pollination and limits breeding between plants of similar genetic heritage (Devreux et al., 1959). This characteristic causes natural populations of this species to present high heterozygosity and genetic variability for several agronomic traits (Van Der Vossen, 1985; Carvalho et al., 1991). To help create plantations with more standardized plants to enhance the cultivation practices, the breeding programs developed clonal cultivars, exploring the advantages of the asexual propagation of a set amount of matrix genotypes (compatible among themselves for pollination). This is to create more homogeneous plantations regarding some agronomic aspects, such as higher uniformity of canopy architecture, ripening time, grain size, among others desirable characteristics (Bragança et al., 2001; Fonseca et al., 2008).

Among the forms of asexual propagation suitable for use in plants of *C. canephora*, the most commonly adopted in commercial nurseries is using cuttings of orthotropic stems to produce new clonal plantlets, this technique is viable in large scale and presents rooting percentage between 95 and 100% (Paulino et al., 1985). The most recent alternative for producing plantlets by cuttings is the use of plastic tubes in nurseries; however, it noticeably increases the production costs per plantlet, due to, among other factors, the requirement of using a more expensive substrate. Therefore, alternatives to decrease the production costs or to increase the quality of coffee plantlets produced in plastic tubes are important research goals.

Coffee husk is an interesting alternative among the materials that could be used to decrease the total amount of required substrate to produce plantlets. This material is a residue produced during the processing of coffee fruits (therefore already available in the coffee producing regions) and it is an excellent source of organic matter, being especially rich in nitrogen and potassium (Dzung et al., 2013; Zoca et al., 2014). However, the proportion in which coffee husk could be use in the mixture to partially replace the commercial substrate is still an incognita, as well as the possible effects that the use of this residue could have over the growth and quality of the plantlets.

In this context, the objective of this experiment was to investigate the influence of using coffee husk as partial component of the substrate to produce plantlets of *C.canephora*; verifying its possible effects over the plant growth, plantlet quality and gas exchange rates.

MATERIALS AND METHODS

Experimental design

The experiment was conducted under controlled conditions, in multiplication nursery specialized in producing clonal plantlets of *C. canephora* Pierre ex Froehner (Conilon coffee), located in the northern state of Espírito Santo, in Southeast Region of Brazil. The experiment followed a 3×6 factorial scheme, in a completely randomized design, studying three genotypes of Conilon coffee and six proportions of coffee husk in the composition of the substrate for plantlets production. Four repetitions were used and the experimental plots were composed by 16 plantlets grown in a 4×4 grid, with evaluations of the four central seedlings protected by borders in all adjacent spaces of the tray.

Selection and multiplication of genotypes

The three genotypes selected to be used in the experiment are components of the clonal cultivar "Vitória Incaper 8142" (National Cultivar Register: #20471) (Brasil, 2006). The grouping of 13 highly productive genotypes composes this cultivar, and, among those, the genotypes referred as 2V, 5V and 12V were selected for this study due to their known contrasting characteristics. Mature stems were obtained from adult matrix plants, from each genotype, grown in clonal garden conduced with bending of orthotropic stems to stimulate sprouting. The plants were standardized on the subject of age, nutritional and phytosanitary aspects. The branches were cut from the middle section of the stems, discarding both ends (apex and base). Cuttings were made from the collected stems, sectioning them in parts of nearly 4 cm of length, using straight cutting on the base and bevel cutting on the apex, and leaving a pair of leaves per cutting with nearly one third of their original area. The cuttings were made following the current recommendation for asexual propagation for plants of Conilon coffee (Ferrão et al., 2012; Verdin Filho, 2014).

Substrate preparation

The prepared cuttings were inserted in plastic tubes of 280 mL of volume, filled with prepared substrate. The substrate was prepared with the standard material used commercially for multiplication of coffee plantlets. To compose the treatments, different proportions of the commercial substrate were replaced by coffee husk to fill the plastic tubes, at the levels of 0, 20, 40, 60, 80 and 100% of replacement, respectively. The plantlets were cultivated in nursery (Figure 1) and their nutrition, irrigation and pest management were made in accordance with current recommendations for plantlets production of Conilon coffee (Ferrão et al., 2012; Prezotti et al., 2007).

Evaluations

The plantlets were evaluated after 120 days of growth in nursery. The plant height (PH) was determined with graduated ruler (precision: 0.1 cm), from the substrate level to the apex of the stem. The total leaf area (LA) per plantlet was obtained using the non-destructive method of linear dimensions (Barros et al., 1973; Brinate et al., 2015). A portable infrared gas analyzer (IRGA, Licor, 6400XT) was used to evaluate the gas exchanges (from

Figure 1. Asexual multiplication using cuttings from matrix plants of each genotype in nursery.
Source: Marilândia, Espírito Santo, Brazil, 2018.

9:00 AM to 11:00 AM in a sunny day). The analyses were performed with irradiance of 1,000 PAR and concentration of CO_2 of 400 ppm. Among other gas exchange parameters, the net carbon assimilation (A), stomatal conductance (gs) and transpiration rate (E) were determined, and the intrinsic water use efficiency (iWUE) was estimated as the between net photosynthetic assimilation of CO_2 and the stomatal conductance.

After these evaluations, the plantlets were cut and each plant compartment (roots, stems and leaves) was separated and placed in paper bags, which were taken to laboratory oven with forced air circulation at 60°C, until constant weight. After drying, the biomass of each organ was stablished in electronic scale (0.001 g of precision). The sum of biomass of all organs was used to calculate the total dry matter (DM). The ratios between biomass accumulated in each organ and the total biomass per plantlet were used to calculate the leaf (LMR), root (RMR) and stem (SMR) mass ratios. The mass ratio between above ground (leaves + stems) and underground (roots) organs were used to calculate the proportion of biomass between shoot and roots (S:R). The ratio between the leaf area and the total biomass of the plantlet were used to calculate the leaf area ratio (LAR).

In addition to the plant height and biomass, the stem diameter was measured with digital caliper (precision: 0.01 mm) in order to estimate the quality of plantlets, which was calculated by the method proposed by Dickson et al. (1960), using the Equation 1:

$$DQ = \frac{TDM}{\frac{PH}{SD} + \frac{DM_{AP}}{DM_{RS}}}$$

Where: DQ: Dickson's quality index; TDM: total dry matter (g); PH: plant height (cm); SD: stem diameter (mm); DMAP: dry matter of aerial part (g); DMRS: dry matter of root system (g).

Data analyses

The data were subjected to analysis of variance and, according to the results for each variable, the interactions were unfolded or the factors studied separately, using the Scott-Knott test for the study the means of the three genotypes and regression analysis for the proportions of coffee husk in the substrate. All tests were performed at 5% probability, using the SISVAR software (Ferreira, 2011).

RESULTS AND DISCUSSION

The total accumulation of biomass (in the form of dry matter), the leaf area ratio, the net carbon assimilation and the quality index of the plantlets were influenced by both factors. Independent effects from the variation originated from the differences among genotypes and among proportions of coffee husk in the substrate, without the occurrence of interaction between these factors was observed.

The comparison among the response of the genotypes is presented in Figure 2, where a faster growth of the plants from the genotype 12V is observed, which resulted in plantlets with higher accumulation of biomass (Figure 2A) and higher quality index (Figure 2D). The genotype 2V seems to present slower initial growth, showing plantlets of lower biomass production (Figure 2A) and lower quality index (Figure 2D) in the end of the same period of time than the other genotypes. The genotype 5V presented intermediate growth between the other two genotypes. The leaf area ratio (Figure 2B) and the photosynthetic rates (Figure 2C) were homogeneous among the three genotypes.

The isolated effect of the proportions of coffee husk in the substrate is presented in Figure 3. The total accumulation of biomass (Figure 3A) presented fit to a 2nd degree linear regression model with maximum point at 38% of replacement of substrate with coffee husk. Similarly, the leaf area ratio (Figure 3B) increased with the use of coffee husk up to the level of 49% of replacement, decreasing after this point. The overall quality of the plantlets (Figure 3D) followed a similar behavior, presenting fit to a 2nd degree linear model with maximum point at 38%. The photosynthetic rate (Figure 3C), however, decreased linearly with the use of coffee husk in the substrate, which caused limitations up to 24% over the net carbon assimilation achieved by the plantlets grown without use of coffee husk. For the

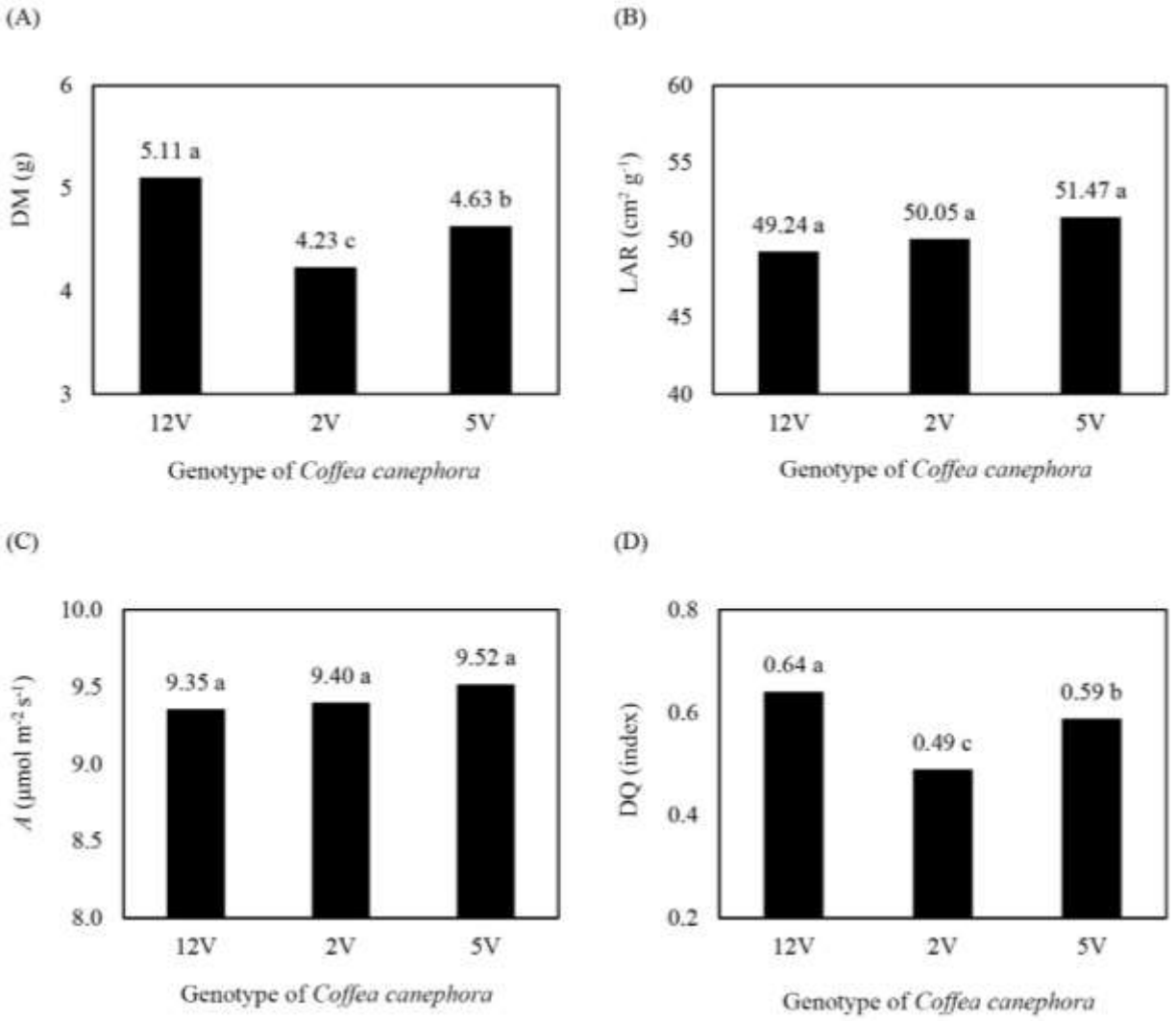

Figure 2. Means of total dry matter (DM), leaf area ratio (LAR), net carbon assimilation (A) and Dickson's quality index (DQ) of plantlets of three genotypes of *C. canephora* (Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability).

remaining variables, there was significant interaction between the effects of genotypes and levels of coffee husk in the substrate; therefore, the unfolding of the interactions was performed. The comparison among genotypes in each level of coffee husk used to replace the commercial substrate is presented on Table 1. For height, the genotype 2V presented the taller plantlets without the use of coffee husk in the substrate, showing that this genotype maybe metabolically invested in the early vertical gain, resulting in taller and thinner stems. For the levels of 20% and 40% of coffee husk in the substrate, the genotype 2V also presented taller plantlets, but the means did not differ from the genotype 12V. Above this level of use, the effects of the coffee husk seem to limit the differentiation among genotypes, resulting in similar means (Table 1).

The leaf area only differed among genotypes for the levels of coffee husk between 40 and 80%. The genotypes 12V and 5V presented larger leaf area for the levels of 40 and 60%, respectively, while the genotype 12V alone presented a higher mean of leaf area for the level of 80%; showing that this genotype invests early in the development of leaves (Table 1). The ratio of biomass between roots and aerial organs seems to be homogeneous among genotypes regardless of the use of coffee husk. The only exception happened with the proportion of 80% of the husk in the substrate. For this isolated condition, the genotype 12V allocated higher amount of its biomass towards the roots than the others did (Table 1). There were significant differences among genotypes for the mass ratio allocate towards each organ (leaves, roots

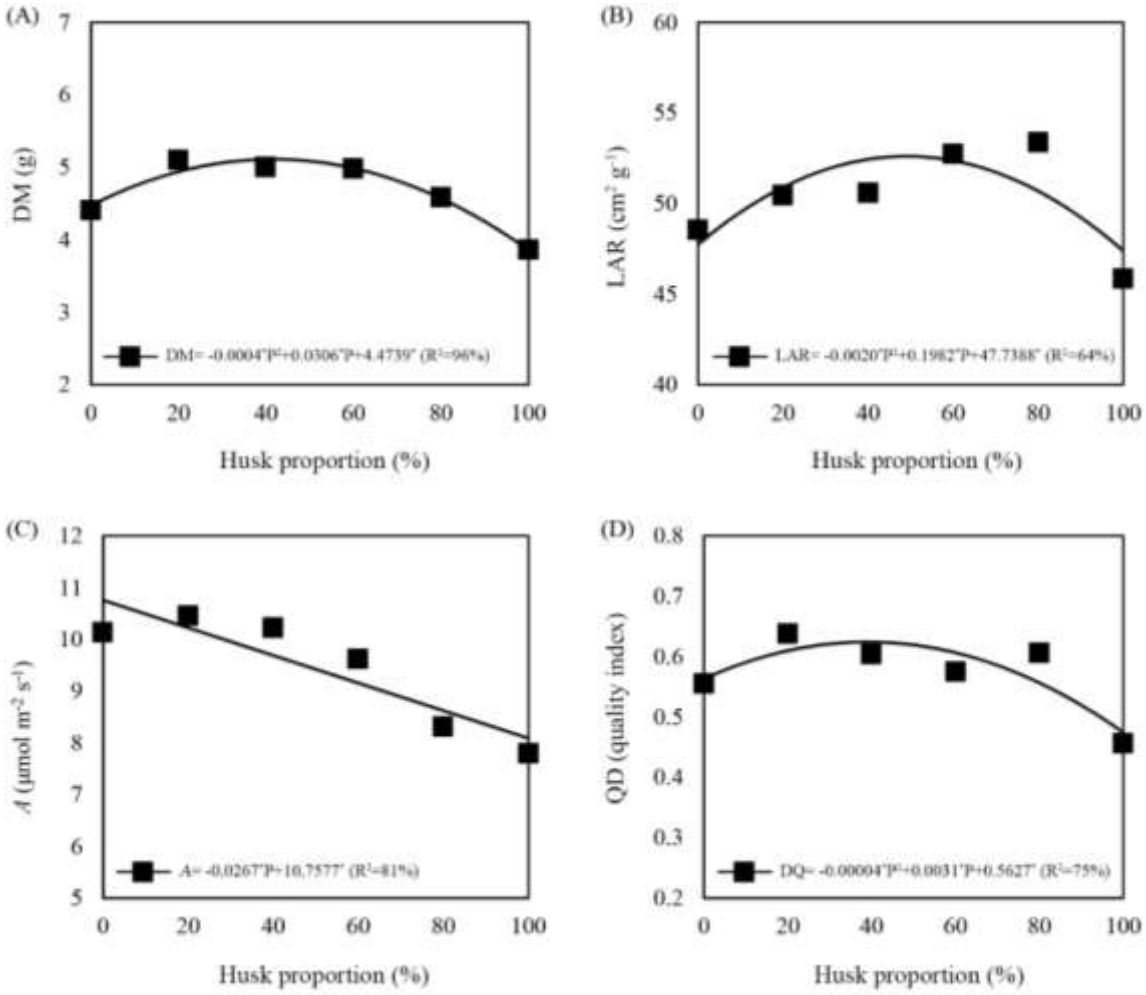

Figure 3. Regression analyzes for total dry matter (DM), leaf area ratio (LAR), net carbon assimilation (A) and Dickson's quality index (DQ) of plantlets of *C. canephora* grown with different proportions of coffee husk in the substrate (Coefficients followed by * are significant by the t-test at 5% of probability).

and stems); however, a similarity of patterns can be observed from the genotypes regardless of the use of coffee husk. Overall, the genotype 2V, compared to the others, seems to have an early allocation of biomass towards the leaves in detriment of stems (Table 1).

The unfolding of the effect of the use of coffee husk for each studied genotype is presented in the regression analyzes of Figure 4. Even if the magnitude of the coefficients is different, a similar pattern of response can be noticed among the genotypes. For the growth in height (Figure 4A) and leafiness (Figure 4B), the genotypes 12V and 5V present significant fit to linear regression models of 2nd degree, with maximum points at the levels of 46% (12V) and 43% (5V) of replacement of substrate with coffee husk for plant height, and at 46% (12V) and 49% (5V) for leaf area. The genotype 5V had both the plantlet height and leafiness decreasing linearly with the use of coffee husk (Figure 4A and B).

The mass ratios were not significantly influenced by the proportion of coffee husk in the substrate, each genotype keeping its own pattern of biomass allocation unchanged. Therefore, these variables did not present adjustment to linear regression models (Figure 4C, D, E and F). In relation to the other parameters of gas exchange, there was significant interaction between the factors for stomatal conductance, transpiration rate and for intrinsic water use efficiency. The factors did not cause significant effects over the intercellular CO_2 concentration. The comparison among genotypes in each level of coffee husk used to replace the commercial substrate is presented on Table 2.

The genotype 2V presented the higher means of stomatal conductance for the plantlets grown without use of coffee husk and up to 40% of replacement. However, its net assimilation of CO_2 was not enhanced by this behavior; indicating that this may be a specific response of this genotype to environmental factors,

Table 1. Means of plantlet height (PH), total leaf area (LA), mass ratio between roots and shoot (R:S), leaf mass ratio (LMR), root mass ratio (RMR) and stem mass ratio (SMR) of plantlets of three genotypes of *C. canephora* for each level of coffee husk used in the substrate.

Husk proportion (%)	Genotype	PH (cm)	LA (cm^2)	R:S ($g\ g^{-1}$)	LMR ($g\ g^{-1}$)	RMR ($g\ g^{-1}$)	SMR ($g\ g^{-1}$)
0	12V	8.21[b]	227.99[a]	0.20[a]	0.23[b]	0.17[a]	0.60[a]
	2V	13.22[a]	223.08[a]	0.20[a]	0.26[a]	0.17[a]	0.57[b]
	5V	8.30[b]	189.20[a]	0.21[a]	0.21c	0.18[a]	0.61[a]
20	12V	11.70[a]	268.28[a]	0.21[a]	0.22[b]	0.17[a]	0.61[a]
	2V	11.50[a]	238.07[a]	0.20[a]	0.24[a]	0.16[a]	0.59[a]
	5V	9.25[b]	264.72[a]	0.21[a]	0.23[b]	0.18[a]	0.60[a]
40	12V	11.73[a]	275.73[a]	0.21[a]	0.22[b]	0.18[a]	0.61[a]
	2V	11.41[a]	220.00[b]	0.21[a]	0.25[a]	0.17[a]	0.58[b]
	5V	9.25[b]	259.49[a]	0.20[a]	0.23[b]	0.16[a]	0.61[a]
60	12V	12.21[a]	290.56[a]	0.20[a]	0.22[b]	0.16[a]	0.62[a]
	2V	10.69[a]	208.04[b]	0.18[a]	0.27[a]	0.15[a]	0.58[b]
	5V	10.14[a]	290.65[a]	0.19[a]	0.21[b]	0.16[a]	0.63[a]
80	12V	10.00[a]	286.19[a]	0.24[a]	0.22[b]	0.19[a]	0.58[a]
	2V	10.15[a]	211.45[b]	0.20[b]	0.27[a]	0.17[b]	0.56[b]
	5V	8.82[a]	234.70[b]	0.20[b]	0.23[b]	0.17[b]	0.60[a]
100	12V	7.21[a]	168.60[a]	0.17[a]	0.23[b]	0.14[a]	0.62[a]
	2V	9.02[a]	168.88[a]	0.16[a]	0.29[a]	0.14[a]	0.57[b]
	5V	7.44[a]	190.56[a]	0.17[a]	0.22[b]	0.14[a]	0.64[a]

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability.

such as humidity, vapor pressure deficit differences and temperature, which may not be observed in the same intensity in the other genotypes grown in the same conditions. Above the proportion of 60%, there was not differentiation among the behavior of the genotypes for the stomatal conductance (Table 2). The transpiration rate was relatively homogenous among genotypes, only presenting differences for the plantlets grown with use of 80% of coffee husk in the substrate and above. Plantlets from the genotypes 4V and 2V presented higher transpiration rates at the levels of 80 and 100% of use of coffee husk in the substrate (Table 2).

The water use efficiency presented difference among genotypes for most levels of coffee husk used in the substrate, only not differing at the levels of 40 and 80%. The genotype 12V presented higher efficiency than the others when grown without use of coffee husk did. Overall, for the plantlets grown using coffee husk in the substrate, this genotype together with the genotype 5V presented the higher water use efficiencies (Table 2). This fact may be related to the investment in stem growth and leafiness, which the genotypes 12V and 5V presented in the same conditions, which may have promoted the development of a more robust transport system to sustain the carbon metabolism of the larger leaves (Table 1). The unfolding of the effect of the use of coffee husk over the remaining gas exchange parameters for each studied genotype is presented in the regression analyses of Figure 5. For stomatal conductance, it was observed that only the behavior of the genotype 12V presented adjustment to linear region model of 2nd degree, with maximum point at 50% of coffee husk use. The genotypes 2V and 5V presented linear decrease in the stomatal conductance with the use of coffee husk, with a sharper decrease being observed for the genotype 2V, as observed by the higher angular coefficient from its regression model (Figure 5A).

The transpiration rate was similarly affected by the proportion of coffee husk used in the substrate for all genotypes. The intensity of the effect and the regression coefficients presented differences, but all genotypes presented adjustment to linear regression models of 2nd degree, with minimum points at 44, 74 and 42% for the genotypes 2V, 12V and 5V respectively (Figure 5B). The genotypes 2V and 5V

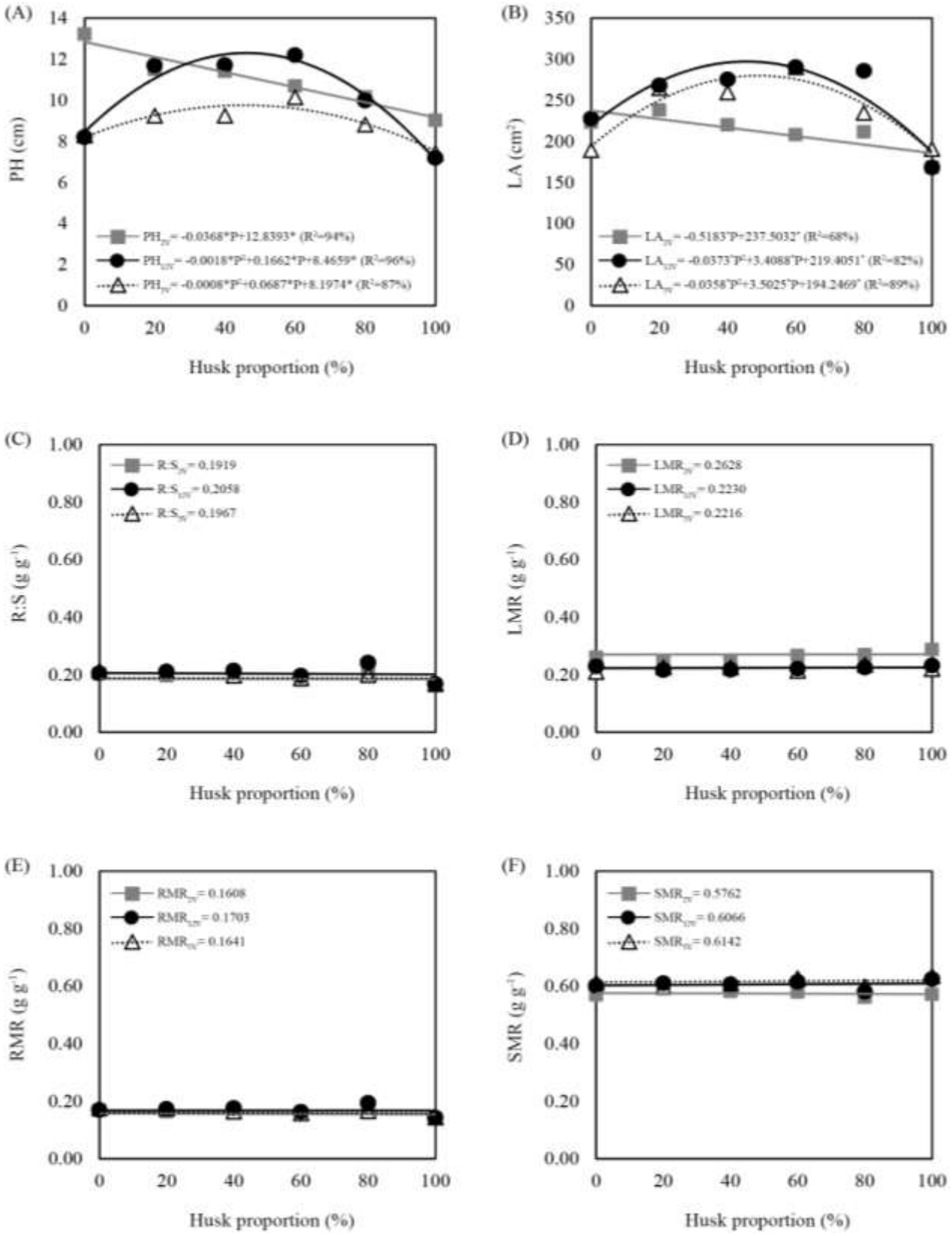

Figure 4. Regression analyzes for plantlet height (PH), total leaf area (LA), mass ratio between roots and shoot (R:S), leaf mass ratio (LMR), root mass ratio (RMR) and stem mass ratio (SMR) of plantlets of *C. canephora* grown with different proportions of coffee husk in the substrate, considering three different genotypes (Coefficients followed by * are signifi cant by the t-test at 5% of probability).

Table 2. Means of stomatal conductance (gs), transpiration rate (E) and intrinsic water use efficiency (WUEi) of plantlets of three genotypes of *C. canephora* for each level of coffee husk used in the substrate.

Husk proportion (%)	Genotype	Gs (mmol m^{-2} s^{-1})	E (mmol m^{-2} s^{-1})	WUEi (µmol mol^{-1})
0	12V	124.57c	4.93[a]	72.94[a]
	2V	293.20[a]	4.94[a]	37.15c
	5V	225.98[b]	4.53[a]	47.65[b]
20	12V	243.52[b]	4.68[a]	43.66[a]
	2V	361.24[a]	4.32[a]	28.95[b]
	5V	223.18[b]	4.53[a]	47.58[a]
40	12V	237.96[b]	4.30[a]	44.85[a]
	2V	298.48[a]	3.95[a]	35.97[a]
	5V	218.60[b]	4.30[a]	44.23[a]
60	12V	228.93[a]	4.14[a]	45.55[a]
	2V	245.88[a]	3.88[a]	35.96[b]
	5V	193.46[a]	3.92[a]	52.08[a]
80	12V	191.84[a]	3.92[b]	42.10[a]
	2V	192.83[a]	3.80[b]	45.60[a]
	5V	200.60[a]	4.73[a]	40.43[a]
100	12V	154.32[a]	4.63[b]	50.18[a]
	2V	202.29[a]	5.96[a]	37.59[b]
	5V	178.42[a]	5.29[b]	46.76[a]

Means followed by the same letter do not differ statistically by the Scott-Knott test at 5% probability.

were not affected by the use of coffee husk regarding the water use efficiency; while the genotype 12V presented adjustment to a linear regression model of 2nd degree with minimal point at the level of 61% of coffee husk being used in the substrate, increasing again after this point (Figure 5C).

Overall, the use of a small proportion of coffee husk in the substrate seem to have some beneficial effects over the initial growth of the clonal plantlets in nursery, and most its detrimental effects started being observed for proportions above 38% of replacement. This result may be related to the composition of the coffee husk, as the main secondary metabolites present beneficial antioxidant properties (Farah and Donangelo, 2006; Shemekite et al., 2014). However, the high content of tannins and phenolic compounds presented in the chemical composition of coffee husk can inhibit the root growth (Shemekite et al., 2014; Fan et al., 2003; Murthy and Naidu, 2012), causing detrimental effects over the development of the plantlets. This effect was observed in this experiment, especially for the biomass accumulation and the quality of the plantlets, which were initially enhanced by the use of coffee husk in the substrate but decreased when high proportions of coffee husk were used.

The search for alternatives of use and disposal of the coffee husk has a great environmental importance, as the anaerobic decomposition of this residue potentially leads to an increase in greenhouse gas emissions. The chemical composition and richness of mineral nutrients of coffee by-products, such as coffee husk, allow them to be used as potential fertilizers, especially after treatment through oxygen-driven biological methods (Murthy and Naidu, 2012; Insam and Bertoldi, 2007). Another important aspect is the possibility of decreasing the dependency to chemical fertilization and non-renewable sources, allowing the exploration of nutrient and energy cycling to enhance economic, agricultural and environmental efficiencies of the crop (Higashikawa et al., 2010).

The use of coffee husk as nutrient source is possible due to its rich organic matter, being a high-quality source of nutrients such as potassium. Some advantages of using coffee husk for partial replacement of the chemical fertilization are enhancing the soil fertility, improving the absorption of nutrients, promoting the growth rate and coffee yield (Dzung et al., 2013). Furthermore, organic residues, such as coffee husk, have potential to be used as partial substitute of vermiculite and other non-renewable materials for the

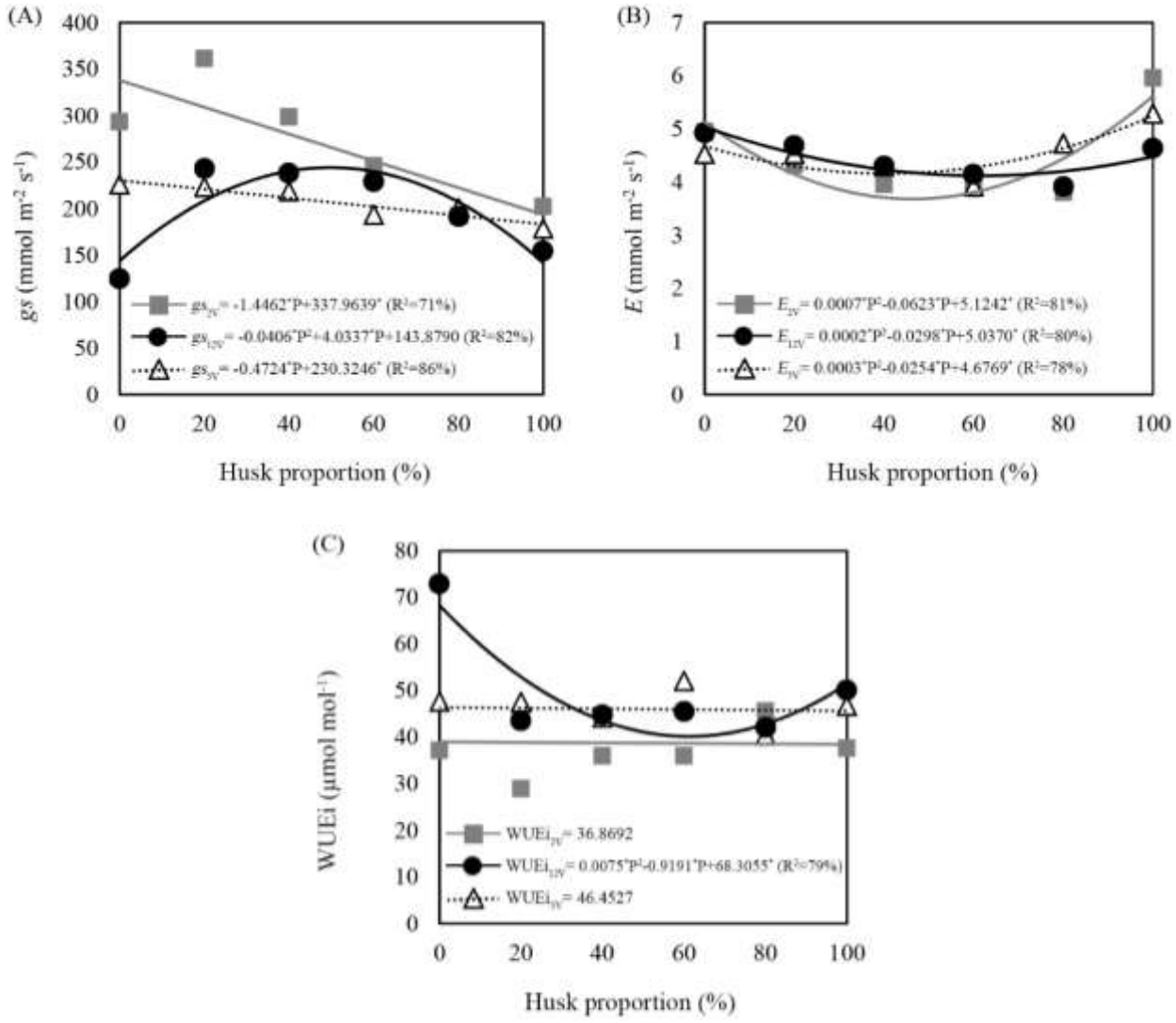

Figure 5. Regression analyzes for stomatal conductance (gs), transpiration rate (E) and intrinsic water use efficiency (WUEi) of plantlets of *C. canephora* grown with different proportions of coffee husk in the substrate, considering three different genotypes (Coefficients followed by * are significant by the t-test at 5% of probability).

production of seedlings and plantlets. Likewise, the agronomic efficiency of the process can be improved by using mixtures or dilutions of the by-product to create a sustainable substrate (Higashikawa et al., 2010; Benito et al., 2006; Melo and Silva, 2008). The results showed that a mixture of commercial substrate with up to 38% of coffee husk might be an adequate initial composition to be explored in further researches aiming to define a proper recommendation. Another fact that may have contributed to the alterations in the gas exchange rates (especially the limitations caused over the stomatal conductance, carbon assimilation and water use efficiency) is the effect of coffee husk over the electrical conductivity of the water in the substrate. The use of coffee husk in higher proportions may increase the electrical conductivity above adequate levels, affecting the osmotic balance, decreasing the efficiency of water absorption and negatively affecting the plant growth and efficiency of their gas exchanges (Higashikawa et al., 2010).

The difference in responses among the genotypes is due to high phenotypic and genotypic variability of the species. Other studies with the same genotypes have showed that beside the existence of diversity of growth patterns among them, there is also different patterns of response to environmental changes related to the soil conditions and fertility (Martins et al., 2013; Contarato et al., 2014; Colodetti et al., 2014). This must be taken in consideration when planning for the multiplication of the plantlets.

Conclusion

The coffee husk is a residue that may be used in mixtures in the substrate to promote plantlet growth and quality; however, this by-product can cause detrimental effects on the net photosynthetic rate, growth and quality of the plantlets if used in high proportions. Largely, the results suggest beneficial effects of the replacement of substrate with coffee husk up to the level of one third of the total volume used in the plastic tubes, with most negative effects showing above the level of 38% of substitution. There are different patterns of response to the use of coffee husk, therefore the before mentioned effects may show with different intensities depending on the genotype, which must be taken into consideration by further researches to help define safety levels and a possible recommendation to use coffee husk in the substrate.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors are grateful to the Consórcio Pesquisa Café and Empresa Brasileira de Pesquisa Agropecuária (Embrapa) for their financial support. They are also appreciative of the Centro de Ciências Agrárias e Engenharias (CCAE) of the Universidade Federal do Espírito Santo (UFES), for providing access to the necessary facilities and tools.

REFERENCES

Barros RS, Maestri M, Vieira M, Braga-Filho LJ (1973). Determination of leaf area of coffee (*Coffea arabica* L. cv. 'Bourbon Amarelo'). Revista Ceres 20(107):44-52.

Benito M, Masaguer A, Moliner A, Antonio R (2006). Chemical and physical properties of pruning waste compost and their seasonal variability. Bioresource Technology 97:2071-2076.

Bragança SM, Carvalho CHS, Fonseca AFA, Ferrão RG (2001). 'Encapa 8111', 'Encapa 8121' 'Encapa 8131': clonal varieties of conilon coffee for the Espírito Santo State, Brazil. Pesquisa Agropecuária Brasileira 36(5):765-770.

Brasil (2006) National Cultivars Register: Vitória Incaper 8142. Brasilia, MAPA. (In Portuguese)

Brinate SVB, Rodrigues WN, Martins LD, Colodetti TV, Tomaz MA, Amaral JFT (2015). Applicability of the method of linear dimensions to estimate leaf area in improved genotypes of Coffea arabica and Coffea *canephora*. American Journal of Plant Sciences 6:651-658.

Carvalho A, Medina Filho HP, Fazuoli LC, Guerreiro Filho O, Lima MNA (1991). Genetic aspects of coffee. Revista Brasileira de Entomologia 14(1):135-183.

Colodetti TV, Rodrigues WN, Martins LD, Tomaz MA (2014). Differential tolerance between genotypes of conilon coffee (Coffea *canephora*) to low availability of nitrogen in the soil. Australian Journal of Crop Science 8:1835-2707.

Companhia Nacional de Abastecimento – CONAB (2018). Monitoring of the Brazilian harvests: cofee. Brasília, Conab. (In Portuguese)

Contarato CC, Tomaz MA, Alves FR, Sobreira FM, Jesus Junior WC, Rabello LKC, Ferrão MAG, Ferrão RG (2014). Reaction of Cultivar Coffee 'Vitória INCAPER 8142' of Conilon to Parasitism of Meloidogyne exigua. Idesia 32:93-97.

Devreux M, Vallaeys G, Pochet P, Gilles A (1959). Recherches sur l'autosterilité du caféier robusta (Coffea *canephora* Pierre). Série Scintifique 78:1-44.

Dickson A, Leaf AL, Hosner JF (1960). Quality appraisal of white spruce and white pine seedling stock in nurseries. Forestry Chronicle 36:10-13.

Dzung NA, Dzung TT, Khanh VTP (2013). Evaluation of coffee husk compost for improving soil fertility and sustainable coffee production in rural central highland of Vietnam. Resources and Environment 3(4):77-82.

Fan L, Soccol AT, Pandey A, Soccol CR (2003). Cultivation of Pleurotus mushrooms on Brazilian coffee husk and effects of caffeine and tannic acid. Micologia Aplicada International 15:15-21.

Farah A, Donangelo CM (2006). Phenolic compounds in coffee. Brazilian Journal of Plant Physiology 18:23-36.

Ferrão RG, Fonseca AFA, Ferrão MAG, Verdin Filho AC, Volpi PS, DeMuner LH, Lani JA, Prezotti LC, Ventura JA, Martins DS, Mauri AL, Marques EMG, Zucateli F (2012). Conilon coffee: production techniques for improved cultivars. Vitória, Incaper. (In Portuguese)

Ferreira D (2011). SISVAR: A computer statistical analysis system. Ciência e Agrotecnologia 35:1039-1042.

Fonseca AFA, Ferrão RG, Ferrão MAG, Volpi PS, Verdin Filho AC, Fazuoli LC (2008). Cultivars of robusta coffee. In: Carvalho CH. Cultivars of coffee: origins, characteristics and recommendations. Brasília, Embrapa Café. (In Portuguese)

Higashikawa FS, Silva CA, Bettiol W (2010). Chemical and physical properties of organic residues. The Revista Brasileira de Ciência do Solo 34(5):1742-1752.

Insam H, Bertoldi M (2007). Microbiology of the composting process. In: Golueke C, Bidlingmaier W, Bertoldi M, Diaz L. Compost Science and Technology. New York, Elsevier.

Martins LD, Tomaz MA, Amaral JFT, Bragança SM, Rodrigues WN, Reis EF (2013). Nutritional efficiency in clones of conilon coffee for phosphorus. The Journal of Agricultural Science 5:130-140.

Melo LCA, Silva CA (2008). Influence of digestion method and sample mass on the recovery of nutrients in organic residues. Química Nova 31:556-561. (In Portuguese)

Murthy PS, Naidu M (2012). Sustainable management of coffee industry by-products and value addition – a review. Resources, Conservation and Recycling 66:45-58.

Paulino AJ, Matiello JB, Paulini AE (1985). Production of plantlets of conilon coffee by cuttings: technical instructions about the coffee cultivation in Brazil. Rio de Janeiro, IBC/GERCA. (In Portuguese)

Prezotti LC, Gomes JA, Dadalto GG, Oliveira JA (2007). Guidelines for recommendation of liming and fertilization for Espírito Santo State.Vitória, SEEA/Incaper/CEDAGRO. (In Portuguese)

Shemekite F, Gómez-Brandón M, Franke-Whittle IH, Praehauser B, Insam H, Assefaa F (2014). Coffee husk composting: an investigation of the process using molecular and non-molecular tools. Waste Management 34(3):642-652.

Van Der Vossen HAM (1985). Coffee selection and breeding. In: Clifford MN, Wilson KC. Coffee: botany, biochemistry and production of beans and beverage. London, Croom Herm, Westport, Conn.

Verdin Filho AC, Mauri AL, Volpi PS, Fonseca AFA, Ferrão RG, Ferrão MAG, Rodrigues WN, Andrade Júnior S, Colodetti TV (2014). Growth and quality of clonal plantlets of Conilon coffee (Coffea *canephora* Pierre ex A. Froehner) influenced by types of cuttings. American Journal of Plant Sciences 52148-2153.

Zoca SM, Penn CJ, Rosolem CA, Alves AR, Neto LO, Martins MM (2014). Coffee processing residues as a soil potassium amendment. International Journal of Recycling of Organic Waste in Agriculture 3:155-165.

Vol. 13(50), pp. 2836-2854, 13 December, 2018
DOI: 10.5897/AJAR2018.13436
Article Number: E49811F59506
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Farmer-based dynamics in tissue culture banana technology adoption: a socio-economic perspective among small holder farmers in Uganda

Murongo M. Flarian[1, 2]*, Ayuke O. Frederick[3], Mwine. T. Julius[1,2] and Wangai K. John[4]

[1]Faculty of Agriculture, Uganda Martyrs University P. O. Box, 5498, Kampala, Uganda.
[2]African Center of Excellence in Agro ecology and Livelihood Systems- Uganda Martyrs University P. O. Box, 5498, Kampala, Uganda.
[3]Department of Land Resources and Agricultural Technology, College of Agriculture and Veterinary Sciences, University of Nairobi, P. O. Box 29053-00625, Nairobi, Kenya.
[4]Department of Plant sciences, College of Agriculture and Veterinary Sciences, University of Nairobi, Kenya.

Received 6 August, 2018; Accepted 19 September, 2018

The rates at which tissue-culture banana technology at smallholder farmer level in Uganda are adopted have reduced since the late 1990s. The study assessed the socio-economic factors influencing adoption of this technology by smallholder farmers. A survey on 280 smallholder farmers sampled from Western Uganda was conducted and responses were subjected to principal component analyses. There are evidences of very low levels of adoption of the tissue culture banana technology. There is a mix between households that completely reject tissue culture banana technology, and others growing diminutive amounts of tissue culture bananas alongside non-tissue culture banana varieties. The scale of production and productivity of non-tissue banana varieties significantly exceeds that of tissue culture bananas (83%: 17%). While expected yield from a banana production technology is a precursor to its adoption, demographic and management characteristics shape the practices that enhance the yield of tissue culture banana technology ($p \leq 0.05$) and subsequent decision to adopt or reject tissue culture banana technology. A systems-wide approach is needed to develop mechanisms that would stimulate smallholder farmers to adopt the technology in order to realize the immense potential of tissue-culture banana technology.

Key words: tissue culture banana; adoption, rejection, socio-economic, banana yield, a systems wide approach.

INTRODUCTION

Banana *(Musa* spp.) is one of the earliest crop plants to have been domesticated, (Kamira et al. 2016) originally planted, and adapted to the humid tropics and the broad subtropical climatic conditions (Murielle et al., 2015). They provide a staple food for millions of people of diverse ethnic groups in Africa (Surendar et al., 2013; Ochola et al., 2015), and consumed in various forms (Anyasi et al., 2013). The banana consumption methods

have not only evolved but have also been refined by humans over time (IFAD, 2012). They are eaten raw, cooked, baked, steamed or fermented (Ravi, 2013). In many places, the whole fruit plant is exploited with uses drawn from leaves, pseudo stem, medicinally rich plant sap or fiber. Other than their edible fruit, the bananas are grown for specific purposes that have become interwoven with the social cultural and livelihood benefits of the human society (Ravi, 2013). Whereas, it is quite true that bananas are versatile, the present discussions have often times more than not fallen short of addressing the socio economic dynamics within smallholder farmers affecting the adoption of the new technologies that come along with the development of this fruit crop. Some studies generally tag adoption of the new banana technologies to the levels of diversity of cultivars on the market, (Changadeya et al., 2012), and the extent to which the technology addresses smallholder farmers' agronomical problems (Changadeya et al., 2012; Langat et al., 2013; Husen et al., 2017), as well as how the new technologies lead to increased production and profit (Dube 2017). Such factors inform farmers' cultivar predilections and socio-economic needs to be met when choice from the available diversity is made.

The smallholder farmers are the major implementers of the developed banana production technologies and also co-experimenters in the development of agricultural technology (Bongers et al., 2012), and live by the results of research. These farmers' knowledge allows for development of farming systems and procedures essential in accepting banana cultivars that give good yield. The cultivars usually adopted are those adapted to the social and ecological circumstances within which the smallholders live and operate (Mwangi and Kariuki, 2015). Recent trends in increased suburbanization (UBOS, 2010) and a significant drop in the incomes of traditional cash crops in Uganda (MAAIF, 2011) gradually led to the commercialization of banana production in the country (UBOS, 2016).

The tissue culture banana (TCB) is a biotechnological agricultural improvement based on the ability of many plant species to regenerate a whole plant from a single shoot tip; developed widely for use in commercial banana production (Wandui et al., 2013). The technology was extended to the small holder farmers as a package that included disease and pest free plantlets, information on crop husbandry, and post-harvest handling practices (Nguthi, 2007). The introduction of tissue culture banana technologies to smallholder farmers was primarily aimed at meeting the commercial demands in banana production, (Mbaka et al., 2008), draw smallholder farmers out of poverty (IFAD, 2009), and enhance food security across the East African countries (Kalyebara et al., 2002; IFAD, 2009; MAAIF, 2011; Godfrey et al., 2014; Alex et al., 2016). However, the acceptability of the technology by smallholder farmers has continued to wobble. For instance, by 2003, according to Akankwasa et al. (2016), two hundred and fifty mother gardens had been established and 40,000 tissue cultured plantlets distributed in Uganda; however, results of the same study show that about 6% of the farmers are willing to select varieties that have gone through the tissue culture production process . Many of the smallholder farmers chose local types as their most preferred varieties (Mwangi and Kariuki 2015; Akankwasa et al., 2016). Smallholder farmers are able to compare production potentials of tissue culture originated banana against the land races. Whereas the former are preferred on production potentials; they are still regarded as inferior with respect to consumption characteristics. In the choice of planting materials, the smallholder farmers tend to ignore the current tissue culture technology products and remain hooked to land race banana types (AAA genomes), with Matooke and Mbidde being the most common of the land races. It is uncertain which specific socio economic factors are major players in the rejection and discontinuance of the tissue-culture banana technology. The need to concretize the factors for non-adoption and discontinuance after adoption of tissue culture banana by smallholder farmers is vital.

MATERIALS AND METHODS

Study area description

A survey was carried out in Uganda among smallholder farmers in the mid-western region comprising the districts of Mbarara, Ibanda, Kiruhura and Isingiro. The specific locations of smallholder farmers are geo-referenced. The area lies between coordinates 1° 00'N and 32° 00'E. It occupies a surface area of 241,551 km^2, of which 17% (41,025 km^2) is water mass. Only 34 % (69,000 km^2) of the land is arable. Permanent crops mainly coffee, and bananas cover 22,500 km^2 which is 33% of the total arable land. Generally, the climate is warm and humid. Altitude of 1800 masl is the main determinant of rainfall in the study area, with variations occasionally induced by topography (UCA, 2009). The rainfall patterns of the area are bimodal with a maximum annual average ranging between 800 and 1,200 mm, annually, with the rains received in March, April, October, and November (NEMA, 2016). The climate is generally tropical. The temperature is 2°C, but always high in the dry periods

*Corresponding author. E-mail: mmurongo@umu.ac.ug, mamenmarius@gmail.com. Tel: +256702414427.

of June, and the driest month of July,

The study area was a beneficiary of *"Agricultural Productivity Enhancement Program"* (APEP) technology transfer program for Uganda 2003 to2008. This program used field demonstrations as a means to increasing banana productivity. Through the demonstration plots, some smallholder farmers were exposed to appropriate tissue-culture banana technologies that included improved banana crop management practices involving use of both organic fertilizers (e.g., manure and mulch) and inorganic fertilizers to restore soil fertility. In addition, selected farmers received planting materials including tissue-culture banana plantlets.

Study design

An explanatory mixed methods research design was followed. Quantitative data were backed up with qualitative information from focus-group discussions and interviews. A cross-sectional survey was used to obtain factors limiting smallholder farmers to adopt tissue culture banana technology. Surveys are done to obtain information relating to the respondents (Denscombe, 2010). In this particular study, the respondents are smallholder banana farmers defined under section 1.2.3. A self-administered questionnaire was used to elicit socio-economic information relating to general banana production at smallholder farm level. Through triangulation various aspects of tissue culture banana phenomena were compared. Such phenomena included among others, comparing age against preference for tissue-culture banana, household leadership and the type of banana grown. Triangulation further helped in validating and verifying the accuracy of quantitative information (Ajay and Micah, 2014).

The unit of analysis and target population

The "unit of analysis" for this study was the smallholder farmer. The study defines smallholder farmer as a farmer who has grown bananas and lived on the same land, shared banana food resources from a common source and contributed to the resource pool of the household for a period not less than fifteen years. This definition became part of the specific criteria developed to determine the purposive sample population for the study.

Resident banana farmers in the study area formed the target population. Smallholder farmers who have been in banana production for at least fifteen years were largely considered. This span of time covers the pre-tissue culture banana period to the present period of tissue culture banana technology in the study region. Key informants included agricultural extension workers and researchers. These provided extensive and reliable information required validate data provided by other respondents.

Sample size and sampling design

Before actual sample size was determined, it was necessary to determine the population size of the target population. However, for this study, the actual population of the smallholder farmers engaged in tissue culture production was not known from the start due to limited data bases available at the districts, the mosaic nature of the farmers, as well as the absence of records from the farmers themselves. Further still, tissue culture banana growing follows a fluid-miscellany character. The study employed the Hyper geometric method adopted from Wackerly et al. (2008) to estimate the unknown population The population was then estimated using the margin of error of ±0.05 as defined by Ajay and Micah (2014). A deviation higher or lower than 5% from the mean was accepted thus giving a confidence level at 95%. Standard deviation, that is, the degree of variance the study expected from the responses was 0.5. (Ajay and Micah, 2014). This figure was a safe estimate for the surveys that have not been administered. For this study, 50% was the most lenient estimation which ensured that the population size was large enough. The confidence level selected corresponds to a Z-score of 1.96; hence the estimated population size determination followed the formula.

$$N = (Z - score)^2 * SD * {(1 - SD)}/{(mE)^2}$$

Where, *N* is the required sample size, *SD* is the standard deviation = (0.5), *mE* is the margin of error = (0.05).

$$N = (1.96)^2 * 0.5 * {(1 - 0.5)}/{(0.05)^2}$$

(3.8416 x 0.25) / .0025
0.9604 / 0.0025
384.16
385

At a margin of error of 0.05, standard deviation of 0.5, and confidence level of 95%, the population size for the study was 385 smallholder farmers. Since the estimated study population is small, the study assumed the calculated population size to be the sample size of the survey. However, there was need to further calculate the true sample of the population in order to determine the minimum number of smallholder banana farmers that would be sufficient to have a 95% confidence interval, with a 5% margin of error in the results. Hence the finite population was determined using the formula;

$$Ts = \frac{(n \text{ x } N)}{(n + N - 1)}$$

Where, Ts = True sample of the population, n = Sample size of the study, N = Population of the sample.

$$Ts = \frac{(385 \text{ x } 385)}{(385 + 385 - 1)}$$
$$Ts = 192.75$$
$$True\ sample = 193$$

The minimum number of respondents for the survey that would achieve a CI of 95% and 5% margin of error was 193 smallholder farmers. Respondents were proportionally distributed to each of the districts in the study region, such that the maximum number of respondents for each of the four districts did not exceed 95 and did not decline below 48. The distribution was further guided by purposive sampling in three major ways. Purposive sampling placed the farmers into categories based on resource endowments, and

Table 1. Descriptive criteria for resource bequest classification of farmers in western Uganda.

Respondent category	Description characteristics
Extraordinary	High level of education (tertiary education) Land holding above 5 acres Regular contact with researchers and extension staff Recurrently used hired professional labor in banana production Have permanent and pensionable employment Have means of communication and get quick feedback
Ordinary	Young households with moderate resource base Variable land holding between 1-3 acres Limited access to credit due to lack of, or insufficient mortgage Irregularly hire in labor or provide outside labor Minimal access to researchers and extension agents
Peasant	Inadequate income to buy inputs for banana production Land holding below one acre Not regular members of social groups They are major source of labor for the first two groups Very low levels of education

Adapted from: Ayuke (2010).

ability to sufficiently grasp the issues of tissue culture banana production.

Data collection

The survey was conducted between August 2017 and January 2018 in four districts viz. Ibanda, Isingiro, Kiruhura, and Mbarara, from the western region of the country in a multi-phase data collection strategy that involved orientation, key informant interviews and focus group discussions. A structured questionnaire was administered face to face to 280 farmers to collect quantitative data on the study parameters. The face to face approach provided an opportunity for auxiliary probing into the parameters under assessment. A composite index of descriptive criteria was developed with categories including; extraordinary, ordinary, peasant categories (Table 1) to facilitate composition of focus group discussions. The classification used was not mutually exclusive, but those who fulfilled most of the criteria were assigned to a specific category.

For each district, nine farmers constituted a focus group discussion, with priority being given to the farmers who possessed knowledge and experience about banana production. Four Focus Group Discussions (FDG) were carried out with a total of 36 farmers from the four districts in the region.

Analysis of data

Data were analyzed with Statistical Package for Social Sciences software (SPSS, version 16.0; Kirkpatrick and Feeny, 2008). Statistical results were regarded significant at P values ≤0.05. Variables were classified as explanatory, and response variables. Only the explanatory variables that showed significant responses towards adoption and production of tissue culture banana were included in the analysis. The factors were isolated through principle component analysis (PCA). Principle component analysis was further used to check for multi-colinearity. Multi-colinearity can inflate the standard errors in explanatory variables, (Myers and Well, 2003), causing failure to reject the null hypothesis when the data actually support its rejection (Denscombe, 2010), and thus lead to the wrong conclusions (Akinwande et al., 2015).The variables that returned the eigenvalue of ≥1, variance inflation factor (VIF) between ≥1 and ≤10, and tolerance levels above 50% , (Akinwande et al., 2015) showed that there were no multi-colinearity symptoms and so the factors were used for further analysis.

RESULTS

Principle component analyses

The empirical estimation to test the influence of socioeconomic factors on tissue culture banana technology adoption at smallholder farm level is in this section. Principle components of the factors under study were isolated. The first two components with the highest eigenvalues (4.719) and (3.599) respectively accounted for 25.2% of the total variance of all factors (Table 2) with first and second components accounting for 14.3 and 10.9% variance, respectively. The progressive left over variances as accounted for by other component factors continually reduced to 4.02%; accounted for by the last component. This distribution gave a sense of how much alteration there was in the eigenvalues from one component. The sum of all PCA canonical eigenvalues showed that the component factor loading related to the type of banana grown explained 47.2% of the total 69.1%

Table 2. Component eigenvalues isolated for the factors involved in tissue culture banana adoption

Component		1	2	3	4	5	6	7	8	9	10	11
Initial Eigenvalues	Total	4.719	3.599	2.569	2.378	1.778	1.732	1.454	1.324	1.166	1.070	1.015
	% of Variance	14.300	10.907	7.786	7.205	5.388	5.247	4.405	4.013	3.534	3.243	3.076
	Cumulative %	14.300	25.206	32.992	40.197	45.585	50.832	55.237	59.250	62.784	66.027	69.103
Extraction Sums of Squared Loadings	Total	4.719	3.599	2.569	2.378	1.778	1.732	1.454	1.324	1.166	1.070	1.015
	% of Variance	14.300	10.907	7.786	7.205	5.388	5.247	4.405	4.013	3.534	3.243	3.076
	Cumulative %	14.300	25.206	32.992	40.197	45.585	50.832	55.237	59.250	62.784	66.027	69.103
Rotation Sums of Squared Loadings	Total	3.584	3.353	2.449	2.234	1.888	1.795	1.653	1.570	1.547	1.405	1.327
	% of Variance	10.860	10.160	7.422	6.769	5.721	5.438	5.010	4.758	4.688	4.257	4.020
	Cumulative %	10.860	21.020	28.443	35.212	40.933	46.371	51.380	56.138	60.826	65.084	69.103

Source: Survey data 2017.

cumulative proportion of variance among the major factors that influenced the adoption of tissue culture banana at smallholder farm level.

Components with eigenvalues ≥1 (in this case explaining less than 4.02% variance) were regarded diminutive for use in further analysis. This is because, they accounted for a non-significant variance from the original variable whose initial significance is 1. Principal components analysis redistributed the variances in the correlation matrix for the first components extracted, and so controlled multi-colinearity, The factors whose absolute values were not closer to 50%, (Kaiser 1974; Anastasiadou 1996; Vertania 2011; Newing et al., 2011) were excluded from further analysis. The 18 factors that met the Kaiser Normalization criteria were placed between components 1 and 11 (Table 3)

The component factors were rotated to reduce the number of factors on which the variables under investigation had high loadings. Management of the planting materials and labor for the value chain substantially loaded onto component 1, at 82.9 and 62.1% respectively. Type of banana grown, variety of the tissue culture banana, treatment of propagation materials, and source of planting materials substantially loaded variables onto component 2, with strength above 65% for each of the loading factor. Household management and the total size coverage by tissue culture banana loaded substantially onto component 3, at 68.2 and 76.5% respectively. Source of income was loaded at 80% onto component 4. Cost of production factor was loaded onto component 5 (66.7%), while all estimated banana bunch yield factors were substantially loaded onto component 6 (46.7, 53.1 and 69.5%).

Substantial loadings onto factor 7 include gender of the farmer (70.3%) and land tenure (57.8%). Age of the farmer was loaded onto component 9 at 53.3% substantial strength. Preference factors were substantially loaded onto component 10. Finally, land use type was heavily loaded onto component 11 with a substantial loading strength of 90.2%. Whereas more than 50% variance is explained by the first six components, and substantially would be considered for further analysis; the other component loadings after component six [gender, age, land use, land tenure, and product preferences] were retained due to their contribution to qualitative socio-economic aspects.

Survey descriptions

Explanatory factors

The largest number of participants by gender

Table 3. Rotated component matrix of factor loadings from principal component analysis.

Component	1	2	3	4	5	6	7	8	9	10	11
Gender of the farmer							0.703				
House hold management			0.682								
Age of the farmer									0.533		
Size covered by TCB			0.765								
Land tenure							0.578				
Type of banana grown		0.931									
Variety of TCB grown		0.660									
Propagation materials		0.938									
Source of the materials		0.840									
Materials Management	0.829										
Labor for the value chain	0.621										
Cost of production					0.667						
Source of income				0.800							
Product preference										0.747	
Land use											0.902
Yield of cooking banana						0.467					
Yield of beer banana						0.531					
Yield of dessert banana						0.695					

Extraction method: Principal Component Analysis0; Rotation Method: Varimax with Kaiser Normalization0; Rotation converged in 11 iterations.
Source: Survey data 2017.

were males 61.1% (n=171) versus 38.9% (n=109) females. Gender distributions cut across several age categories (Table 4).

Three forms of land tenure were considered and responses indicated that 71.4% (n=200) of the smallholder farmers operate on land inherited from their parents and benefactors, while the remaining 28.6% operated on leased land hold or freehold land tenure systems. The responses on labor for the value chain in tissue culture banana production indicate that 73.2% (n=205) rely on family labor for production while the remaining 26.8% on hired professional labor and community labor. Responses on cost of production indicated that 60% (n=168) were viewed as the factor limiting the production of tissue culture banana. Other factors include cost of planting materials (11.8% n=33), limitation by transportation costs for the materials (18.9% n=53), expenses on field hygiene (7.5% n=21), and land acquisition costs (1.8% n=5).

Another concern on socio -economic aspects manifests in household management dynamics. About 55.4% (n=155) respondents indicated that households are mainly headed by the husband although a significant number of households are headed by females (31.4% n=88). In some instances, 3.2% (n=9) of the households are headed by children, while 10% (n=28) of the households are under the charge of guardians and benefactors. For the smallholder farmers' source of income, most of the farmers 68.6% (n=192) depend on income arising from sales from subsistence produce. The remaining 31.4% depend on a number of sources; among them are gifts and donations, (11.1%, n=31), wage employment (9.3%, n=26) agricultural loans (6.1%, n=17), and permanent and pensionable employment (5.0%, n=14)

The response factors

Response factors (Table 5) indicate that 80.7% (n=226) are non-adopters of tissue culture banana production technologies. Farmers who have adopted or those willing

Table 4. Explanatory variables in the adoption of tissue culture banana by smallholder farmers.

Factor	Category	N	Percent
Gender of the farmer	Male	171	61.1
	Female	109	38.9
Age of the farmer	18-29	57	20.4
	30-49	114	40.7
	50-74	102	36.4
	75+	7	2.5
Land tenure	Land inherited from parents	200	71.4
	Leased land	36	12.9
	Free hold	44	15.7
Labor for the value chain	Hired/Professional labor	40	14.3
	Family Labor	205	73.2
	Community Labor	35	12.5
Cost of production	Costs of labor	168	60.0
	Cost of TCB planting materials	33	11.8
	Costs for Field hygiene	21	7.5
	land acquisition costs	5	1.8
	Transportation costs	53	18.9
Household management	Husband is the head	155	55.4
	Wife is the head	88	31.4
	Children are the head	9	3.2
	Guardian is the head	28	10
Farmers' source of income	Permanent/pensionable source	14	5.0
	Wage employment	26	9.3
	Sales from subsistence production	192	68.6
	Agricultural Loans	17	6.1
	Gifts and donations	31	11.1

Source: Survey data 2017.

to adopt the technology 42.1% (n=118) can only allocate less than 25% of the total land to the production of tissue culture under smallholder production. Meanwhile, 83.2% (n=233) of the smallholder farmers did not use tissue culture plantlets for establishment of new banana plantations or for replacement of the damaged plants. Responses on the source of planting materials showed that 68.9% (n=193) used planting suckers from their own farms as opposed to 31.1% (n_{total}=87) of the farmers who received suckers from government projects, undefined neighborhood plantations, or research outlets.

More than 75% of the farmers grow non tissue culture cooking banana, whereas 24.3% grow tissue culture cooking banana, and other varieties. Notable among this category was the (0.4%) single farmer growing tissue culture dessert banana, and 17.9% (n=50) of the farmers in the region growing tissue culture cooking banana. This distribution is an epitome of non-adoption of the technology by smallholder farmers.

The yield factor variation

Smallholder farmers understand yield in an infrequent way of articulating units of measurement for the banana; the banana bunch, a unit of measurement clearly

Table 5. Response variables in the adoption of tissue culture banana technology.

Variable	Category	Frequency (n)	Percentage	Mean
Response variables				
Type of banana grown	Tissue culture banana	54	19.3	1.81±.395
	Non tissue culture banana	226	80.7	
Type of propagation materials	Plantlets	47	16.8	1.84±.374
	Conventional suckers	233	83.2	
% size of the field covered by TCB	1-25%	118	42.1	2.17±1.217
	26-50%	65	23.2	
	51-75%	28	10.0	
	75-100%	24.6	24.6	
Source of planting materials	Research outlet centers	15	5.4	2.86 ±.674
	Government projects	40	14.3	
	Farmers' own suckers	193	68.9	
	From neighborhoods	32	11.4	
Variety of the Banana grown	Tissue culture cooking banana	50	17.9	1.97±.735
	Non tissue culture cooking banana	212	75.7	
	Non Tissue culture Beer banana	15	5.4	
	Tissue culture Dessert banana	1	0.4	
	Non Tissue culture Dessert banana	2	0.7	

Source: Survey data 2017.

understood by the smallholder farmers but rather incoherent with the metric system in establishing the exact quantity of solid banana in possession. The total yield (in bunches) for cooking banana, brewing banana and dessert banana types was compared (Figure 1).

The yield for non-tissue culture cooking banana was higher for all responses. The mode for yield occurrence indicates lower numbers for the yields between zero and 500 bunches for estimated five consecutive production cycles, with the extraordinary farmers producing above 4,500 bunches for the five cropping cycles.

The production of dessert banana is much lower compared to the cooking type. Farmers produce about 3-5 bunches of dessert banana through the five production cycles as the lowest mode of occurrence. The highest single farmer recorded about 280 bunches of dessert banana over the five production cycles. Meanwhile, the production of beer banana in the region is not given much importance compared to cooking banana, although, beer banana production is much higher compared to dessert banana types. There are observable lower modes of occurrence at lower numbers of bunches produced for beer banana, with the highest single farmer producing about 470 bunches for the five consecutive production cycles.

A reasonably interesting input about the comparison of yield for banana types of the tissue culture origin and the non-tissue culture land race banana from the interviews and ratified by focused group discussions is that all key informants agree that tissue culture banana gives good yield because they are clean; free from pests and diseases. It was further revealed during the FDG 1 by the participant thus;

"It is not because the "Kawanda Bananas[1]" do not give a better yield, but because this better yield is short-lived. The tissue culture banana types hardly sustain productivity for five years. It is therefore, not necessary for [us] to venture into a project that would not last"

Other strong sentiments were expressed in terms of cost and taste preference by small holder farmers. Some of the sentiments were captured by the questionnaire and summarized under section 2.2.4.

[1] The name by which tissue culture bananas and other hybrid banana types are called by the small holder farmers.

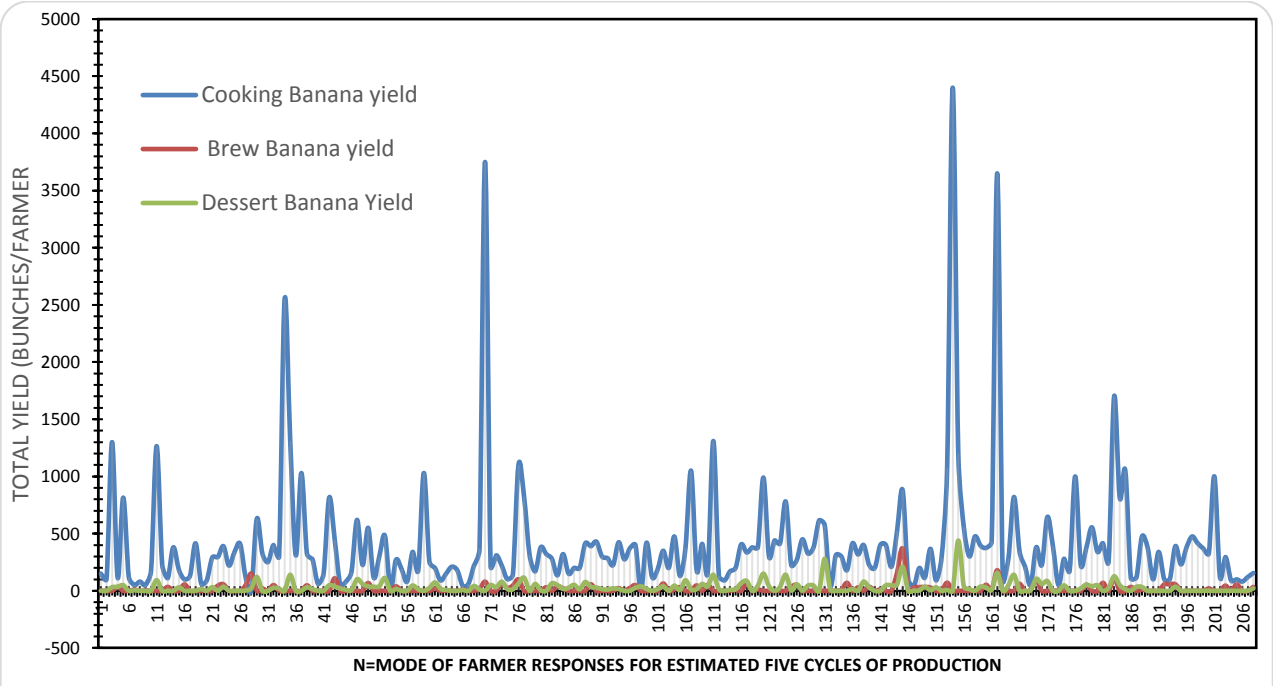

Figure 1. Yield factor estimations for the adoption of tissue culture banana.
Source: primary data.

Survey on market and preference factors

Market for the different types of banana grown in the region and the preference for consumption of the banana products were interrogated in the field (Table 6).

91.2% of the responses indicated that non-tissue culture cooking banana types (59.1% [n=167]) and non-tissue culture dessert banana types [32.1% (n=90)] have high market demand with attractive prices. However, in terms of preference for consumption, it was shown that 81.4% (n=228) of the population prefer to consume non tissue culture cooking banana type. Responses on market demand and consumption preferences for all tissue culture banana types were less than 13% for all the types combined together. For the peculiar submission on preferences during FDG 2 in Ibanda district, a female participant expressed concern about the current generation bananas,

“I sell bananas in my stall. Usually, the ‘Kawanda bananas’ are given a higher price, because they appear big in size, and have a smooth skin. Our local bananas are small and often times spotted; but in a single day, I receive more clients demanding for local types than the Kawanda types except in cases where these bananas are purchased for parties, then we benefit from their high prices”

This qualitative submission brings out the background meaning embedded in the preferences and cost attached to the types of banana. It further gives a clue on the identification and differentiation of tissue culture and non-tissue culture banana types.

Regression analyses

A linear model was used to estimate the probability of a positive influence of explanatory factors towards the adoption of tissue culture banana technology by smallholder farmers. Marginal effects computed for the socio -economic factors and their influence on tissue culture banana technology adoption in this model measured the expected change in the probability of observing a positive influence on the tissue culture banana technology with respect to a change in the particular yield response variable. In terms of the overall percentage of predictions correctly classified, the model performed well for all PCA isolated explanatory and response variables, thus implying a good fit. "Tolerance" and "Variance Inflation Factor"(VIF) values for all the predictor variables ruled out multi-colinearity to a higher

Table 6. Market and Preference considerations in smallholder banana production.

Parameter	Value						
Banana type has a high market with attractive prices							
				Valid			
	1	2	3	4	5	6	Total
Frequency	6.0	167.0	8.0	8.0	1.0	90.0	280
Percent	2.1	59.6	2.9	2.9	0.4	32.1	100
Valid Percent	2.1	59.6	2.9	2.9	0.4	32.1	100
Cumulative Percent	2.1	61.8	64.6	67.5	67.9	100.0	
Banana type is most preferred for consumption							
Frequency	13	228	1	2	34	2	280
Percent	4.6	81.4	0.4	0.7	12.1	0.7	100
Valid percent	4.6	81.4	0.4	0.7	12.1	0.7	100
Cumulative percent	4.6	86.1	86.4	87.1	99.3	100	

1= Tissue culture cooking banana; 2= Non tissue culture cooking banana; 3= Tissue culture brewing banana;, 4= Non tissue culture brewing banana; 5= Tissue culture dessert banana; 6= Non tissue culture dessert banana.
Source, survey data 2017.

estimation. The tolerance value indicates the fraction of variance in the predictor that cannot be accounted for by the other predictors. Tolerance values obtained for this study (Table 7a, b, c) explained variances that were large enough (all above 60%) to rule out predictors that were redundant (small values ≤ 10%). The most independent predictor at 97.7% level of tolerance was costs of production involved in the production of tissue culture banana. Labor for the value chain independently predicted 97.5%, while land tenure systems variance prediction could be tolerated at 89.7%. Age of the farmers could be tolerated as an independent predictor of yield at 77.2%. Household management independently predicted yield by 71.3% level of tolerance. Farmers' source of income and gender of the farmers showed the least levels of tolerance at 69.2 and 66.9%, respectively. All predictor variables indicated variance inflation factor values ≥1and ≤ 10, (Table 7a, b, c), thus the variables did not merit further interrogation and exploration. Gender, household management, labor sources for banana production value chain, land tenure systems, and costs involved in the production of banana were significant contributors to yield of cooking banana ($P<0.05$) (Table 7a).

Only age of the farmers significantly contributed to yield of beer banana ($P=0.005$) (Table 7b). Age of the farmers, household management and farmers source of income significantly contributed to yield of dessert banana ($P<0.05$) (Table 7c).

Source of the materials and management of the planting materials significantly determined the yield of the cooking banana type ($P< 0.005$). There is a very strong and significant relationship between source of the materials, and the type banana grown, variety of tissue culture banana and management of the sourced materials ($P<0.05$) (Table 8).

Whereas there is a significant interaction between individual factors that act together to determine the yield of beer banana, the overall factors' interaction shows no effect on the yield of beer banana. Each of the factors significantly interact with at least one factor to determine the yield dynamics of the beer banana (Table 9).

There is a significant relationship when two individual factors interact in causing an effect on the yield of dessert banana. However, when all factors are combined together, their overall effect on the yield of dessert banana is insignificant. Each of the factors significantly interacts with at least one factor to determine the yield dynamics of the dessert banana (Table 10).

DISCUSSION

The empirical results estimating the influence of socio-economic factors on tissue culture banana technology adoption at smallholder farmer level are discussed in this section. The study hypothesized that socioeconomic factors influencing the tissue culture banana technology uptake are not farmer -based, and so are beyond the smallholder farmer. For small holder farmers to accept tissue culture banana technologies, the foremost consideration is the yield benefit accruing from the

Table 7a. Regressed predictor factors for yield approximate for cooking banana (bunches/farmer)
Source; survey data 2017

Model		Coefficients											
		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
	(Constant)	7.685E2	2.888E2		2.661E0	0.008	1.999E2	1.337E3					
	Gender	-2.571E2	9.133E1	-0.199	-2.815E0	0.005	-4.369E2	-7.733E1	0-.142	-.168	-.163	.669	1.495E0
	Age of the farmer	-5.855E1	5.251E1	-0.073	-1.115E0	0.266	-1.619E2	4.482E1	-0.169	-0.067	-0.064	0.772	1.296E0
	Level of education	3.534E1	4.578E1	00.052	.772	0.441	-5.479E1	1.255E2	0.046	0.047	0.045	0.736	1.358E0
1	House hold management	1.190E2	4.591E1	00.178	2.593E0	0.010	2.866E1	2.094E2	0.130	0.155	0.150	0.713	1.402E0
	Labor for the value chain	-1.526E2	7.176E1	-00.125	-2.126E0	0.034	-2.938E2	-1.128E1	-0.152	-0.128	-0.123	0.963	1.038E0
	Land tenure	240.498	48.700	00.286	4.938	0.000	144.621	336.375	0.250	0.287	0.271	0.897	1.115E0
	Cost of production	63.469	22.374	00.158	2.837	0.005	19.420	107.518	0.134	0.170	0.156	0.975	1.025E0
	Farmers' source of income	4.989E1	4.930E1	00.070	1.012E0	0.312	-4.717E1	1.470E2	0.031	0.061	0.059	0.692	1.445E0

Dependent Variable: Total Yield approximate of Cooking banana Source: Survey data 2017.

Table 7b. Regressed predictor factors for yield approximate for beer banana (bunches/farmer).

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
	(Constant)	17.602	16.833		1.046	0.297	-15.537	50.741					
	Gender of the	-4.570	5.323	-0.062	-0.859	0.391	-15.049	5.909	0.047	-0.052	-0.051	0.669	1.495
	Age of the farmer	8.633	3.060	0.190	2.821	0.005	2.609	14.658	0.161	0.168	0.167	0.772	1.296
1	Level of education	-2.485	2.668	-0.064	-.931	0.352	-7.738	2.768	-00.099	-00.056	-00.055	00.736	1.358
	House hold management	2.545	2.676	0.067	.951	0.342	-2.723	7.813	0.035	0.057	0.056	0.713	1.402
	Labor for the value chain	-6.846	4.182	-0.099	-1.637	0.103	-15.081	1.388	-0.088	-0.099	-0.097	0.963	1.038
	Farmers' source of income	0.816	2.874	0.020	0.284	0.777	-4.842	6.473	0.100	0.017	0.017	0.692	1.445
	Land tenure	3.222	2.996	0.067	10.075	0.283	-2.676	9.120	0.063	0.065	0.064	0.897	1.115
	Cost of production	-0.669	1.376	-0.029	-0.486	0.627	-3.378	2.041	-0.030	-0.029	-0.029	0.975	1.025

Dependent Variable: Total yield approximate of Beer Banana.
Source: Survey data 2017.

Table 7c. Regressed predictor factors for yield approximate for dessert banana (bunches/farmer).

Model		Coefficients										
		Unstandardized coef.		Standardized coef.	t	Sig.	95% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	26.054	16.496		1.579	0.115	-6.423	58.530					
	Gender of the	-5.943	6.263	-0.065	-0.949	0.344	-18.272	6.387	-0.107	-0.057	-0.053	0.672	1.489
	Age of the farmer	8.793	3.615	0.156	2.432	0.016	1.675	15.910	0.136	0.146	0.137	0.769	1.301
	House hold management	-6.578	3.204	-0.139	-2.053	0.041	-12.886	-0.270	-0.224	-0.124	-0.116	0.691	1.446
	Land tenure	6.536	3.528	0.110	1.852	0.065	-0.411	13.482	0.088	0.112	0.104	0.897	1.115
	Labor for the value chain	7.547	4.933	0.088	1.530	0.127	-2.166	17.259	0.139	0.092	0.086	0.962	1.040
	Farmers' source of income	-9.468	3.165	-0.189	-2.992	0.003	-15.699	-3.237	-0.243	-0.178	-0.169	0.793	1.261
	Cost of production	2.185	1.621	0.077	1.348	0.179	-1.006	5.377	0.109	0.081	0.076	0.975	1.025

Dependent Variable: Total yield approximate of Dessert Banana. Source: Survey data 2017.

Table 8. The relationship between response factors and yield of cooking banana.

Parameter		A	B	C	D	E	F
Sig. (1-tailed)	Yield of Cooking banana (A)	-	0.296	0.093	0.253	0.000	0.000
	Type of banana grown (B)	0.296	-	0.000	0.000	0.000	0.133
	Variety of TCB grown (C)	0.093	0.000	-	0.000	0.000	0.360
	Type of propagation materials(D)	0.253	0.000	0.000	-	0.000	0.025
	Source of the materials (E)	0.000	0.000	0.000	0.000	-	0.000
	Management of the materials (F)	0.000	0.133	0.360	0.025	0.000	.
	N	280	280	280	280	280	280

Source: Survey data 2017.

technology. The yield benefits are related to the inputs such as land, labor and other accessory costs involved in the production of the technology. Besides yield, smallholder farmers are cognizant of the fact that their social values as largely shaped by the culture are preserved. Therefore, a high yielding technology, which corroborates the socio-economic orientations of the farmers is easily accepted. Actually Smith (2007) earlier

Table 9. The relationship between response factors and yield of beer banana.

Parameter		A	B	C	D	E	F
Sig. (1-tailed)	Yield of Beer banana (A)	-	0.233	0.101	0.143	0.221	0.213
	Type of banana grown (B)	0.233	-	0.000	0.000	0.000	0.133
	Variety of TCB grown (C)	0.101	0.000	0.	0.000	0.000	0.360
	Type of propagation materials(D)	0.143	0.000	0.000	-	0.000	0.025
	Source of the materials (E)	0.221	0.000	0.000	0.000	-	0.000
	Management of the materials (F)	0.213	0.133	0.360	0.025	0.000	-
	N	280	280	280	280	280	280

Table 10. The relationship between response factors and yield of dessert banana.

Parameter		A	B	C	D	E	F
Sig. (1-tailed)	Yield of Dessert banana (A)	0.	0.217	0.362	0.172	0.276	0.241
	Type of banana grown (B)	0.217	0.	0.000	0.000	0.000	0.133
	Variety of TCB grown (C)	0.362	0.000	0.	0.000	0.000	0.360
	Type of propagation materials(D)	0.172	0.000	0.000	0.	0.000	0.025
	Source of the materials (E)	0.276	0.000	0.000	0.000	0.	0.000
	Management of the materials (F)	0.241	0.133	0.360	0.025	0.000	0.
	N	280	280	280	280	280	280

Source: Survey data 2017.

argued that that a technology is often valued according to whom it is associated, with, rather than by its utility. Even with a clear comprehension of the "yield decline" narratives in banana production, threats to the economy, livelihoods and food security, a desirable internal momentum within the smallholder farmers has not been created to adopt tissue culture banana technology to solve the threats. Small scale farmers still associate the technology to scientists and policymakers. To these farmers, the technology in reality is more of a burden than a necessity.

Levels of tissue culture adoption in Uganda

The level of adoption for tissue culture banana technology was found to be very low on all traits ranging from acceptance of plantlets, marketing and finally to consumption. Farmers rejected the tissue culture banana products including the plantlets and the harvested products. Fall back for those who had accepted the technology remains eminent. Indicators for non-adoption were evident in the allocation of available resources to the accepted technology. Allocation of land resources to tissue culture banana production was diminutive. Research centers and other government projects lack capacity/ability to shoulder the socio -economic demands that would support the acceptance of tissue culture banana technologies.

The farmers argument that tissue culture banana gives good yield and the reason advanced in their arguments that the planting materials are clean, and free from pests and diseases holds truth and corroborates with Singh et al. (2011), who, in giving deeper meaning to development of tissue culture technology as a foundation of high quality, fronted the fact that planting materials are disease free. An outstanding reason established by this study as to why smallholder farmers hesitate to adopt the technology is mainly the sustainability of the technology. Customarily, banana is grown as a perennial crop where the plant marts produce continuous shoots from a subterranean corm, and depending on the level of management yield may start to decline after ten to fifteen years. In tissue culture banana technologies, the yields fall rapidly after three to five years, thus creating need to shift to cyclic replacement with a new plantation. This practice is expensive and incomprehensible to the smallholder farmers.

Smallholder farmers use suckers from their own orchards. Where the planting suckers are not sufficient,

corms of recently harvested banana are used as planting materials. These corms regenerate into suckers that eventually grow into strong plants. This orientation of planting suckers and corms suggests a direction of thought that diverges from, Tushemereirwe et al. (2003), who assert that use of suckers and corms in banana production perpetuates banana weevil and diseases.. The suckers obtained from farmers' own gardens and from the neighborhoods continue to take precedence. This is due to low cost and availability when compared to plantlets developed by tissue culture processes. The tissue culture banana plantlets are limited to the "resource endowed" farmers. The resource -endowed farmers have the ability to foot the high costs involved in buying, transporting and maintaining the tissue culture banana plants into the fields. It therefore follows that small-scale farmers who are largely not resource bequest will keep within the confines of cheap source of planting materials. Farmers using their farm-derived materials for planting accord them the satisfaction that curtails the need to use cleaned suckers from other sources, thus, propagation of the same surpasses the acceptance and propagation of tissue culture banana.

There is a very strong attachment to production of cooking banana for both social and economic reasons. Actually, smallholder farmers insist on having good and well tendered orchards which raise the social status of the farmers, improve on the social capital, and most importantly, guarantee the food security of the farmer. Smallholder farmers who make substantial food contributions to the communities' social functions are often more respected than those who do not. There is however, a moderate improvement in the production of beer banana types regardless of whether they are tissue culture or non-tissue culture banana. The explanations are vested in the versatility of the products and bi-products, most of which have socio economic orientations. For instance, drawing from the farmer focused discussions; the banana brewing produces *Waragi*[2] that significantly contributes to the income base of the households and the social status of the farmers. Residues from the brewing process are ploughed back into the soil for the production of other banana types. The residues are also important sources of mulch, and feed for animals. Meanwhile, the dessert and cooking banana types are used by some farmers to produce juices that are fermented into alcohol and subsequent production of other residues for use in banana crop production. Thus, the type of banana contributes to the social capital dynamics.

An understanding of the responses in this study is drawn from the fact that the largest number of the participants was males. A review by Mwangi and Kariuki (2015) indicates that gender issues in agricultural technology adoption have been explored for a long time, although, the studies have not been explicit regarding the different roles men and women play in technology adoption (Mignouna et al., 2011; Obisesan 2014; Mwangi and Kariuki 2015). Social systems appear to assign the male gender those practices that are more economically superior. The participation of the male gender is an indicator of the profitability of the banana growing project even at small -holder farmer level. Whereas the females' practices and involvement in banana production projects may greatly be driven by food security orientation (Husen et al., 2017), the men's impetus is in most cases financial (Alinovi et al., 2010). This understanding contravenes earlier arguments that the association between gender and the probability of adoption of agricultural technology is rather not significant. This could be true for other crops such as maize, but untrue in the case of tissue culture banana adoption. Majorly, men are the bread earners in the local family settings and therefore, quickly adopt a practice that supports the economic status of the families. If in this context males have an obligation to provide for the family, and land races provide a greater solution to this duty, then the tissue culture banana technologies cannot benefit either gender in the same way. Therefore, male farmers are more likely to fall back to tissue culture banana production if it enhances the role of the head of the family.

The study established that age has a stake in adoption of new agricultural technology, but does not stand alone in decision making whether to adopt or reject tissue culture banana technology. Mature and experienced farmers have a long term understanding and experience, hence are better placed to evaluate new technology practices and demands than younger farmers. Whereas there is increased risk aversion and decreased interest in long-term investment as the farmers grow old (Obisesan 2014), it would be argued that younger farmers are less risk-averse and therefore would be more willing to take up tissue culture banana production as a new technology. On the contrary, the products from tissue culture process are stagnated even with increased number of younger farmers (20.4%) venturing into banana farming. Dynamics in banana production are largely influenced by 40% of the farmers in the middle age category (30-49 years). This age bracket is indeed a working group and most often result- oriented. The high number of young people engaging in smallholder banana farming is not due to passion as such, but rather an alternative occupation due to limited opportunities for formal employment.

Supporting structures in the banana production practices are enhanced by land tenure systems. Most of

[2]The local name of the spirit distilled from fermented banana juice and yeast. It is used at social functions and for commercial processing of other spirits.

the operational land is inherited from the fore-parents. The study further established that over 80% of the banana plantations are traditional; implying that they have been perpetuated from generation to generation. The social systems usually dictate the conditions for use of such inherited land systems. It can be concluded that tissue culture banana technologies in Uganda are nascent and probably has not caused a strong impact that can be inherited, defended, and sustained by smallholder farmers. Inherited social systems in banana production stretch to the use of labor in banana production (Komarek et al., 2013). Time and time again, smallholder farmers rely frequently on family labor. Family labor benefits from the household size, an indicator of the extent of labor availability in smallholder production systems. It determines adoption process in tissue culture banana production in that, larger households have the capability to subdue the labor limitations vital for tissue culture banana introduction. Other forms of labor, including professional labor are left to the resource endowed and extraordinary farmers. The low adoption rates t reflects a nature of the households such that households cannot raise sufficient labor to offset tissue culture banana production demands.

Over 55% of the households are male headed. Social and economic decisions to accept or reject tissue culture banana production are vested in the household head. Even though much of conservative research accepts that the 'head' of the household is male, farmers' experiences in Uganda currently challenge this orientation. What is conventional in this study is that both male headed and female headed households make decisions that do not support the production of tissue culture banana technology products. Otherwise, the 31% of the households headed by females would make a significant contribution to the acceptance of tissue culture banana products. It is argued in this study that introducing tissue culture banana products to a predominantly subsistence banana biased production systems creates a need for socio economic change first. However, earlier Etwire et al. (2013), Geoffrey (2016) and Bandewar et al. (2017a) observed that socio -economic changes are difficult to achieve in the process of introducing new farming techniques. As long as the smallholder farmer tenaciously holds to landrace banana production as a practice that is socio-economically gratifying, acceptance of the tissue culture banana is not a priority for them.

Yield factor variations and influence for adoption

The premise of the study in this area was that yield is a pertinent factor in the adoption of tissue culture banana technology. This premise is backed by Chitamba et al. (2016), that a technology that brings forth a sustainable yield is definitely accepted by smallholder farmers. An honest; though misleading understanding by the smallholder farmers was that the ability of the banana plants to produce a sustainable amount of bunches to meet family survival needs depends on the total number of suckers a local banana mart holds. The number of suckers produced would be the number of bunches at harvest period. However, yield performance of the banana plant depends on the management by the farmers amidst a host of other biophysical interactions (Wairegi and Asten 2010; Nyombi, 2013; Nakato et al., 2017; Bandewar et al., 2017b). The management practices are constrained by land tenure systems, labor dynamics, as well as level of income and the income sources.

The yield for non-tissue culture cooking banana was higher, with farmers extraordinarily producing about 4500 bunches through the five cropping cycles, while production of beer banana is slightly higher compared to dessert banana types, with extraordinary farmers producing about 300 and 280 bunches respectively. Discussions with the farmers showed that the current changes in social systems promote the use of the different types of bananas variedly. The variations are attributed to the societal dynamics that spill over to the production systems of the banana and the traditional beer parties have since reduced. For instance, cooking banana is an item that forms part of the valued gifts during spiritual and social household gatherings. On the other hand, processing of *Tonto* into a spirit that attracts slightly high prices is slowly attracting the households into the production of beer banana.

Market and consumer preferences

Non-tissue culture bananas attract good prices on the market, and in terms of preference for consumption, the populace prefers non- tissue culture cooking banana type. This result generally agrees with FAO (2014) and UNCTAD (2016), that assert that inclination for traditional banana can incline the preference factors towards the market potential of this banana. The dissenting assertiveness towards tissue culture banana is a result of market considerations for the different types of banana grown in the region. The attitude towards tissue culture banana products is wanting even when there are free channels for the farmers to receive plantlets.

The idea as to whether consumers and sellers can tell the difference on site between tissue culture banana and the land races is inconsistent although several

discussions point to a near judgment. It is observed that, the cost of banana vaguely shows which type it is. It was shown that higher prices are attached to tissue culture bananas but their actual consumption is limited to big social functions. The second aspect is the size, where the bigger the size of the banana, the higher the likelihood of that banana being a 'Kawanda Banana'. The third aspect is the texture. Whereas the landraces are rough and spotted, the bananas of the tissue culture origin are herein described as smooth skin bananas.

Demographic features and their influence of adoption

The study established that gender, household management, labor sources for banana production value chain, land tenure systems, and costs involved in the production of banana were significant contributors to yield of cooking banana. Marginal effects figured out for the socio- economic factors and their influence on tissue culture banana technology adoption in the linear model, measured the expected change in the probability of observing a positive influence on the tissue culture banana technology with respect to a change in the particular yield related to a response variable. Social demographics contribute positively to the decision to adopt a particular banana type and its related technology. In the study, males formed the largest response rate and following studies by Dube (2017) the male gender social constructs role directly links to products that attract high prices. It can then be argued that, the economic returns of the non-tissue culture banana technology are sufficient enough to attract males more than any other gender. This study established that, non-tissue culture banana products attract higher prices on the market compared to any other banana type. The decision to accept, support and finance the new tissue culture banana technology is greatly attached to the male-gender social construct. Males dominate household leadership, thus, have control over labor, land and are entitled to inheritance of other livelihood enhancing resources. Can the same be said for women? Certainly not! What is certain and conventional is that, regardless of age, this gendered 'order' places the women in the responsibility of much of the day-to-day household, family, and on-farm labor activities (Rosemarie, 2010). A popular understanding of a "good wife" varied from district to district. However, the common understanding was that a good wife relates to a measure of how she positively realizes her multiple responsibilities to the household, especially through her prominent role as a farmer contributing to sufficient production of landrace banana.

Households rely mainly on family labor. In most cases family labor is too rudimentary to match the labor demands for tissue culture banana production. Besides, labor is allocated to the banana type that is marketable and consumable by the smallholder farmers. Therefore, the available force is maximized for the production of non-tissue culture banana due to high market and preference requirements. It can further be argued that the labor requirements for production of non-tissue culture banana are lower within the management by the small holder farmers. Other forms of labor are rather expensive to be managed by the smallholder farmers. Besides, particular farmers in the region are worried that if they employed professional labor, it would result in the introduction of the "*Kawanda Bananas*[3]". Professional labor force is visibly insufficient to explain to farmers some of these concepts. As matter of fact, the smallholder farmers blend their understanding of tissue culture bananas, improved or hybrid, bananas and the genetically modified bananas. To farmers, all the three types are the same, and are from the same source, meant to dilute their local land race types.

The results of the study clearly showed that land owned by the smallholder farmers is inherited from the previous owners. The significance of land tenure in influencing the yield and acceptance of non-tissue culture banana production draws from the fact that, land on which production is made is inherited from the fore owners, whose interests and social dictates are usually followed. The source from which land is acquired usually dictates the continuity of the land use and type of production carried out on the same land. Therefore, the inherited and long lasting non-tissue culture traditional banana orchards provide socio-economic benefits that cannot be surpassed by the new technology. Otherwise, the latter would lead to the destruction of the old plantations for re-establishment of tissue culture banana types. This understanding is backed up by yet another finding of the study that the costs involved in tissue culture production value chain in terms of plantlets' development; purchasing, transportation and management in the field are a burden to the small- holder farmers. The alternative plan for the smallholder farmers is to use the farmers' own suckers, and those obtained from the neighborhood. This edges out the production of tissue culture banana products in preference to the conventional less expensive banana type.

Components within the demographic characteristics are significant factors in shaping decisions regarding the uptake of tissue culture banana technology. The attributes attached to the social factors lead to significant yield levels ($P \leq 0.05$), for at least one type of banana produced by small- holder farmers (Table 7a, b, c)

[3] The name by which smallholder farmers know the banana products from the National Research Organization, located at Kawanda.

Interests for adoption vary with age and gender. Age and gender are associated with a short time preference for the types of banana. Hence, they determine the decision to sustain the adoption or fall back to rejection. Other than age, the other demographic variables progressively become negatively associated with the probability of adoption and production of beer banana as the productivity proceeds from cycle to cycle. Although Husen et al. (2017) indicate a negative relationship between age and the adoption of some agricultural technologies in Ethiopia, and Ssentamu et al. (2012) and Rosemarie (2010) disassociated gender issues as a factor in new technology acceptance in Kenya and Philippines respectively, and these are contrary to the findings of this study for Uganda as far as tissue culture banana technology is concerned.

The contributing effect of farm characteristics

Yield remains a precursor to adoption of tissue culture banana technology. The enablers for this yield as predicted by the total number of bunches estimated for five production cycles are source of the materials for planting and the management approaches of the planting materials. They extend to the type of banana grown, method of propagation and the variety of banana grown. These significantly determine the yield of the different banana types ($P< 0.005$). The inter-factor interactions were very strong and significant ($P<0.05$), in determining the yield of the cooking banana. The overall factors' interaction shows no effect on the yield of beer banana ($P>0.05$), but the inter-factor relations in beer banana production are significant, with at least one factor interacting to determine the yield dynamics of the beer banana. Hence, non-adoption of tissue culture banana technologies cannot be blamed on the social and economic factors alone. There are other interacting factors in the process.

CONCLUSIONS AND POLICY DIRECTIONS

This study assessed the dynamics associated with adoption of tissue culture banana technology in Uganda, and established that the levels of adoption of this technology are still low. Above 75% of the farmers grow land race non tissue culture banana. Whereas the percentage of adoption rates for tissue culture banana is generally low for farmers in Uganda; the conclusion may not be generalized for the rest of the banana growing countries of the world, except those that present similar socio economic dynamics under which this study was conducted.

The yield of land race non tissue culture banana type is high due to increased number of farmers and increased acreage under production rather than the adoption of the technology. This orientation is not sustainable because smallholder farmers can have a paradigm shift along the production process. Additionally, land is a fixed asset that may not sustain increased production as a result of increase in acreage under production. Therefore, adoption of the technology would present a better choice for the small holder farmers. However, this would only occur if the technology is convincing enough to overcome the socio economic mindset of the smallholder farmers.

Market and taste preferences favor the non-tissue culture banana types. The farmers are solely responsible for the decision to adopt or reject tissue culture banana technology. This decision is enhanced by age, household leadership, land tenure systems, gender and sources of labor. Sustainability of the yield supports the decision for the smallholder farmers to adopt and sustain the technology, fall back to the former technology, and/or reject and sustain the rejection of the technology.

The indicators for adoption and or rejection become reflected in the size of the land allocated to the technology, choice of the propagation materials, source of the materials for propagation, and types of banana grown. The limitation behind such indicators is the subjectivity and/or objectivity of the farmers. Farmers who may have subjective impressions about the tissue culture banana technology will limit resource allocation to the technology, than the farmers who are objective about the same technology.

Economically poor farmers are labor constrained to sustain tissue culture banana technology demands. Socio- economically unstable smallholder farmers especially of the female gender are in the most precarious situations of all, ready to forego the adoption of tissue culture banana technologies as result of pressure from their social ancestry constitutions.

A systems wide approach is recommended to develop mechanisms that would improve the adoption of the technology in order to tap into its unknown immense advantages. There is a need to understand the smallholder farmers' perceptions of use attributes and the performance of tissue culture banana technologies as compared to the traditional/landrace banana production technologies to give farmers options by context. Finally, there should be a deliberate effort to respond to tissue culture banana adoption problems through processes that would establish a self-sustaining system of production, distribution and utilization of farmer-preferred varieties of tissue culture banana in Uganda. For instance, tissue culture banana processes, and

hardening orchards should be exposed to the farmers not only to reorient the farmers' negative perceptions of the technology, but also to enable farmers' access to banana planting materials.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Ajay S, Micah B (2014). Sampling techniques and determination of sample size in applied statistics research : An overview. International Journal of Economics, Commerce and Management 2(11):1:22.

Akankwasa K, Ortman GF, Tushemereirwe WK, Wale E (2016). Early-Stage Adoption of Improved Banana Matooke" Hybrids in Uganda: A Count Data Analysis Based on Farmers' Perceptions. International Journal of Innovation and Technology Management 13(1):60-86.

Akinwande MO, Dikko HG, Samson A (2015). Variance Inflation Factor: As a Condition for the Inclusion of Suppressor Variable(s) in Regression Analysis. Open Journal of Statistics 5(7):754-767.

Alex A, Makindara J, Tumwesigye G, Sikira A (2016). Assessment of Existing Policy and Legal Framework for Banana Value Chain Development in Uganda. International Journal of Asian Social Science, 6(2):146-165. Available at: http://www.pakinsight.com/archive/1/02-2016/2.

Alinovi L, D'errico M, Erdgin M, Romano R (2010). Livelihoods Strategies and Household Resilience to Food Insecurity : An Empirical Analysis to Kenya. https://ec.europa.eu/europeaid/sites/devco/files/erd-socpro-sp-alinovi-romano-derrico-mane-201006028_en_0.pdf

Anastasiadou SD (1996). The Development and Validation of a New Scale for Monitoring Students' Attitudes to Learning Statistics with Technology. http://www.cerme7.univ.rzeszow.pl/WG/8/CERME%207_WG8_Anastasiadou.pdf

Anyasi TA, Jideani AIO, Mchau GRA (2013). Functional Properties and Postharvest Utilization of Commercial and Noncommercial Banana Cultivars. Comprehensive Reviews in Food Science and Food Safety 12(1):509-522.

Bandewar SVS, Wambugu F, Richardson E Lavery JV (2017a). The role of community engagement in the adoption of new agricultural biotechnologies by farmers : the case of the Africa harvest tissue-culture banana in Kenya. BMC Biotechnology 17(28):1-11.

Bandewar SVS, Wambugu F, Richardson E, Lavery JV (2017b). The role of community engagement in the adoption of new agricultural biotechnologies by farmers : the case of the Africa harvest tissue-culture banana in Kenya. BMC Biotechnology 17(28):1-11.

Bongers G, Jassogne L, Wanyama I (2012). Understanding and exploring the evolution of coffee-banana farming systems in Uganda. https://www.cabdirect.org/cabdirect/abstract/20133410286

Changadeya W, Kambewa D, Agrrey J (2012). Farmers' adoption potential of improved banana production techniques in Malawi. International Journal of Physical and Social Sciences 2(4):32-48.

Chitamba J, Manjeru P, Chinheya CC, Handiseni M (2016). Current banana smallholder farmers' farming practices and knowledge on plant-parasitic nematodes associated with banana (Musa spp.) in Rusitu Valley, Zimbabwe. African Journal of Agricultural Research 11(13):1120-1125.

Denscombe M (2010). The Good Research Guide for small scale social research projects Fourth Edi., Berkshire: Open University Press.

Dube L (2017). Farmer to Farmer Extension and Adoption of Improved Farming Practices : Evidence from Manicaland and Masvingo Provinces of Zimbabwe. Scholars Journal of Agriculture and Veterinary Sciences 4(6):214-222.

Etwire PM, Al-hasan RM, Kuworu JKM, Osei-owusu Y (2013). Smallholder farmers' adoption of technologies for adaptation to climate change in Northern Ghana. Journal of Agricultural Extension and Rural Development, 5(July), pp. 121–129.

Food and Agriculture Organization (FAO) (2014). Intergovernmental group of Food and Agriculture Organization of the United Nations (FAO) Market and Policy Analyses of Raw Materials, Horticulture and Tropical (RAMHOT)n bananas and tropical fruits,

Geoffrey S (2016). Modelling Climate Variability and Climate Change and Their Associated Effects on Highland Cooking Banana Production in Uganda By a thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy in Meteorology, University of Nairobi.

Godfrey B, Mwine J, Jumba F, Murongo M, Njoroge NG, Kabango F (2014). Assessing the effectiveness of ethno medicinal products on banana weevils using REML science publishing group. Agriculture, Forestry and Fisheries 3(5):420-426.

Husen NA, Loos TK, Siddig KHA (2017). Social Capital and Agricultural Technology Adoption among Ethiopian Farmers. American Journal of Rural Development, 5(3):65-72.

IFAD (2009). Enabling poor rural people to overcome poverty in Uganda Rural poverty in Uganda P 12. Available at: http://www.ifad.org/operations/projects/regions/Pf/factsheets/uganda.pdf.

IFAD (2012). Republic of Uganda Area-Based Agricultural Modernization Programme Project Performance Assessment, https://www.ifad.org/documents/38714182/39732924/aamp.pdf/e1f98c00-2b13-46a9-9711-a29026bc8378

Kaiser HF (1974). An index of factorial simplicity. Psychometrika 1(1):1-3.

Kalyebara R, Wood S, Abodi PN (2002). Assessing the Potential Impact of Selected Technologies on the Banana Industry in Uganda, UBOS pp. 141-154

Kamira M, Ntamwira J, Sivirihauma C, Ocimati W, Asten P, Vutseme L, Blomme G (2016). Agronomic performance of local and introduced plantains, dessert, cooking and beer bananas (Musa spp.) across different altitude and soil conditions in eastern Democratic Republic of Congo. African Journal of Agricultural Research 11(43):4314-4332.

Kirkpatrick L, Feeney B (2008). A Simple Guide to SPSS for Version 16.0. https://books.google.co.ug/books/about/A_Simple_Guide_to_SPSS_for_Version_16_0.html?id=fLzThaPn85AC&redir_esc=y

Komarek MA, Ahmadi-Esfahani FZ (2013). The impact of changing marketing conditions on Ugandan banana farmers. Journal of Agribusiness in Developing and Emerging Economies 2(1):74-88.

Mbaka JN, Mwangi M, Mwangi NM (2008). Farming as a Business : The Role of Tissue Cultured Planting Materials in Kenya. Journal of Applied Biosciences 9(1):354-361.

Mignouna B, Manyong M, Rusike J, Mutabazi S, Senkondo M (2011). Determinants of Adopting Imazapyr-Resistant Maize Technology and its Impact on Household Income in Western Kenya: AgBioforum 3(14):156-163.

Ministry of Agriculture Animal Industry and Fisheries (MAAIF) (2011). National Agriculture Policy. http://agriculture.go.ug/the-national-agriculture-policy-nap/

Murielle MT, Bielders CL, Asten Van PJA (2015). Field Crops Research Short- and medium-term impact of manual tillage and no-tillage with mulching on banana roots and yields in banana-bean intercropping systems in the East African Highlands. Field Crops Research 171:1-10. Available at: http://dx.doi.org/10.1016/j.fcr.2014.10.015.

Mwangi M, Kariuki S (2015). Factors Determining Adoption of New Agricultural Technology by Smallholder Farmers in Developing Countries. Journal of Economics and Sustainable Development 6:5. Myers JL, Well AD (2003). Research Design and Statistical Analysis Second Edi. D. Riegert & J. Planer, eds., Hamilton Printing Company.

Nakato GV, Beed FD, Bouwmeester H, Ramathan I (2017). Building agricultural networks of farmers and scientists via mobile phones : case study of banana disease surveillance in Uganda. Canadian Journal of Plant Pathology 38(3):307-316.
NEMA (2016). National state of environment report for Uganda 2014, Kampala. Available at: http://www.nema.go.ug.
Newing H, Eagle CM, Puri RK, Watson CW (2011). Conducting Research in conservation. A social science perspective, London: Routledge. https://epdf.tips/conducting-research-in-conservation-social-science-methods-and-practice.html
Nyombi K (2013). Towards Sustainable Highland Banana Production in Uganda. African Journal of Food Agriculture, Nutrition and Development 13(2):7544-7561.
Obisesan A (2014). Gender Differences in Technology Adoption and Welfare Impact among Nigerian Farming Households, MPRA Paper No. 58920,
Ochola D, Ocimati W, Tinzaara W, Blomme G, Karamura EB (2015). Effects of water stress on the development of banana xanthomonas wilt disease. Plant Pathology 64(3):552-558.
Rosemarie EG (2010). Social Capital and the Decision to Adopt New Technology among Rice Farmers in the Philippines. Philippine Journal of Development 37(68):1-13.
Singh HP Uma S, Selvarajan R, Karihaloo JL (2011). Micro propagation for Production of Quality Banana Planting Material in Asia-Pacific, New Delhi: Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB). Available at: www.apcoab.org.
Smith J (2007). Culturing Development : Bananas, Petri Dishes and “Mad Science” Culturing Development : Journal of Eastern African Studies 1(2):212-233.
Ssentamu N, Dubois T, Qaim M (2012). Heterogeneous information exposure and technology adoption : the case of tissue culture bananas in Kenya. Agricultural Economics 43:473-485.
Surendar KK, Devi DD, Ravi I, Krishnarkumar S, Kumar SR, Velayudham K (2013). Water Stress in Banana-A Review. Bulletin of Environment, Pharmacology and Life Sciences 2(6):1-18.
Tushemereirwe WK, Kashaija IN, Tinzaara W, Nankinga C (2003). A guide to successful banana production in Uganda. Banana production manual. Second edition. National Agricultural Research Organisation (NARO).
UBOS (2010). Uganda census of agriculture Crop Area and Production Report, Available at: www.ubos.org.
UBOS (2016). Uganda Demographic and Health Survey Uganda Bureau of Statisitcs; Statistical Abstract, https://www.ubos.org/onlinefiles/uploads/ubos/pdf%20documents/Uganda_DHS_2016_KIR.pdf
UNCTAD (2016). United Nations Conference on Trade and Development, New York and Geneva. https://unctad.org/en/Pages/DITC/Trade-and-Environment/BioTrade/BT-Uganda.aspx
Vertania T (2011). Secondary Data Analysis 1st Edition., New York: Ohio State University.
Wackerly D, Mendenhall W, Scheaffer RL (2008). Mathematical Statistics with Applications. 7th Edition., Belmont, CA, USA.: Thomson Higher Education. doi 10.4236/health.2013.58168.
Wairegi LWI, Asten PJA (2010). The agronomic and economic benefits of fertilizer and mulch use in highland banana systems in Uganda. Agricultural Systems 103(8):543-550.
Wandui C, Masiga E, Francis M, Wachira C (2013). Situational Analysis of the Current State of Tissue Culture Application in the Eastern and Central Africa Region, Kampala. Available at: http://www.asareca.org.

Vol. 13(50), pp. 2855-2861, 13 December, 2018
DOI: 10.5897/AJAR2018.13042
Article Number: E4837E159524
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Fertilizer source influence on antioxidant activity of lettuce

Camila Karina Costa e Silva[1], Kelly Barbosa da Silva[2], Paulo Rogério Barbosa de Miranda[3], Tâmara Claudia de Araújo Gomes[4], Jessé Marques da Silva Júnior[3], Mayara Andrade Souza[3], Aldenir Feitosa dos Santos[3] and João Gomes da Costa[3,4]

[1]Programa de Pós-Graduação em Agricultura e Ambiente, Universidade Federal de Alagoas – Campus Arapiraca, Brazil.
[2]Rede Nordeste de Biotecnologia/RENORBIO – Instituto de Química e Biotecnologia, Universidade Federal de Alagoas, Brazil.
[3]Departamento de Mestrado Profissional em Análise de Sistemas Ambientais, Centro Universitário Cesmac, Brazil.
[4]Empresa Brasileira de Pesquisa Agropecuária, Centro de Pesquisa Agropecuária dos Tabuleiros Costeiros, Embrapa Tabuleiros Costeiros. Campus Delza Gitai, Brazil.

Received 6 February, 2018; Accepted 16 October, 2018

Consumers are increasingly aware and concerned about their health and therefore demanding for more healthy and nutritious food. Thus, the demand for organic foods has increased recently. Thus the aim of this study was to compare the antioxidant activity and total phenolic content of lettuce produced in organic and conventional systems. The antioxidant activity of ethanol extracts was determined by the DPPH and FRAP assay. The total phenolics content was obtained spectrophotometrically according to the Folin-Ciocalteu method and calculated as gallic acid equivalent. The organic lettuce showed higher effectiveness in antioxidant capacity and higher levels of phenolic compounds than lettuce produced in the conventional system.

Key words: *Lactuca sativa,* antioxidant potential, agricultural management, dpph frap, phenolics total.

INTRODUCTION

The current concern with men's health has led to a demand for healthier foods, thus providing a better life quality. Some natural products present high levels of antioxidants that are responsible for the prevention of various diseases. Antioxidants are molecules that inhibit or decrease the damages provoked by free radicals (Shahidi and Ambigaipalan, 2015). Free radicals can be produced by exogenous sources or by the natural metabolic reactions.

The human metabolism synthesizes free radicals during its physiological reactions that interact with DNA, RNA, proteins, lipids and polysaccharides causing serious damage as degenerative diseases. Vitamins C and E, phenolic compounds, flavonoids and carotenoids are extremely relevant antioxidants that can be acquired through a balanced diet of vegetable origin (Nizmse and

*Corresponding author. E-mail: joao-gomes.costa@embrapa.br.

Pal, 2015)

The consumption of fruits, cereals and vegetables are effective free radicals that fight foods. According to Borges et al. (2016), some studies indicate that the use of organic fertilizers can influence the synthesis of antioxidant compounds. The organic products are better than the conventional, however the studies comparing foods from both managements still scarce.

Lettuce (*Lactuca sativa* L.), belonging to the Asteraceae family, is native from Mediterranean (Medeiros et al., 2016), but is currently cultivated in innumerous regions and is the most popular and appreciated hardwood vegetable.

The phenolic profile of lettuce is well defined and reported in the literature with caffeic acid derivatives and flavonoids, representing the main component class. However, genetic and environmental factors can influence in the phytochemical profile of plants. Therefore, the variety planted, weather, soil type, the light intensity, irrigation, the supply of nutrients, plage control, the system of cultivation, among others can influence on the chemical content of plants (Sofo et al., 2016; Santos et al., 2014; Perez-Lopez et al., 2018; Durazzo et al., 2014).

Several studies analyzing the antioxidant properties of fruits, vegetables, and medicinal plants have been reported (Talens et al., 2016; Calado et al., 2015; Turati, 2015). However, a few papers show the influence of the cultivation type on antioxidant action of these foods. There is a tendency that organically produced foods have lower nitrate content, highest content of vitamin C and dry matter as well a high content of compounds with antioxidant action, such as flavonoids and carotenoids (Reganold and Wachter, 2016; Baranski et al., 2014; Williams et al., 2016). On the other hand, Aires (2016) showed that the organic foods are similar to conventional ones. However, Baranski et al. (2014) concluded that organic crops present higher concentrations of antioxidants than conventional crops.

It can be seen that there are disagreements about the differences between organic and conventional products on the antioxidants levels. Thus, the aim of this study is to compare the organic and conventional production system over lettuce antioxidant activity.

MATERIALS AND METHODS

The study was carried out in a greenhouse unit with planting being held in 2.5 L vases with 2 treatments types (conventional and organic fertilizer), using 30 samples for each treatment. The fertilization was performed from the soil analysis according to Table 1.

Crude extract obtention

The crude extract was obtained by maceration in ethanol, using the leaves of organic and conventional lettuce. Then the material was dried in an oven at 50°C and crushed at a mill knives; purchasing a dry powder which was submitted to maceration with ethanol 99.5% with filtering every 24 hours for five days. The the material was dried in the 40°C on a rotary evaporator BUCHI Heating Bath B-490. The percentage yield was calculated using the following equation:

$$\text{Yield}(\%)=\frac{\text{Crude extract weight}}{\text{Lettuce Leaves weight}}\times 100 \quad (1)$$

Determination of total phenol content

The total phenol content of the samples was determined by the Folin-Ciocalteau method (Scherer and Godoy, 2014). 100 µL of the methanolic solution of the sample, 500 µL of the aqueous Folin 1:11 (v/v) solution and 400 µL of the aqueous Na_2CO_3 solution (7.5%) were added in eppendorf flasks. The solution was stirred in a vortex for 30 seconds. After an aliquot of 250 µL transferred to 96-well plate, and kept in the dark for 2 hours and analyzed using a plate reader spectrophotometer at 740 nm. The results were expressed in mg Gallic Acid equivalent/g dry extract. All experiments were realized in triplicate.

Antioxidant activity with DPPH

From stock solutions (1.0 mg/mL) of samples of conventional lettuce (CL) and organic lettuce (OL), test solutions were prepared at concentrations of 500 to 6 µg/mL (CL) and the 250 µg/mL (OL). An aliquot of 100 µL of sample test solution were transferred to a 96-well plate and 40 µL of methanolic solution of 2.2-diphenyl-1-picrylhydrazyl (DPPH) 0.3 mM. Blank solution was prepared using 100 µL of sample test solution and 40 µL of methanol for each concentration. Control solution was prepared using methanol (100 µL) and DPPH 0.3 mM. The samples was kept in the dark for 30 minutes and analyzed in a plate reader spectrophotometer at 518 nm. All experiments were realized in triplicate. The antioxidant activity percent was obtained using the follow equation:

$$\text{AAP}(\%)=100-\frac{\text{Abs}_{\text{Sample}}-\text{Abs}_{\text{Blank}}}{\text{Abs}_{\text{Control}}}\times 100 \quad (2)$$

Ferric reducing antioxidant power (FRAP)

The Ferric reducing antioxidant power test was realized as described by Aras et al. (2017). The FRAP test was realized using 30 µL of methanolic sample solution, 90 µL of distilled water and 900 µL FRAP reagent (25 mL of acetate buffer 0.3 M, 2.5 mL of 2,4,6-Tri(2-pyridyl)-s-triazine (TPTZ) 10 mM and 2.5 mL of an aqueous solution of ferric chloride 20 mM). The test solutions were homogenized in the vortex and an aliquot of 250 µL was transferred to 96-well plate and kept at 37°C for 30 min. The sample absorbance was analyzed using a plate reader spectrophotometer at 595 nm. The trolox standard curve was constructed from these test solutions at concentrations of 10 µM a1000 µM. The results were expressed in µM Trolox equivalent/g of extract. All experiments were realized in triplicate (Table 3).

RESULTS AND DISCUSSION

Determination of total phenol content

Varying the concentration of gallic acid, the analytical

Table 1. Fertilization systems and its composition/amount.

Fertilizer	System	Compounds	Amount
Planting $N:P_2O_5:K_2O$ (30:90:60)	Conventional	Urea	70 kg/ha or 0,2 g/vase
		Simple superphosphate	500 kg/ha or 1,4 g/vase
		Potassium chloride	105 kg/ha or 0,3 g/vase
		Dolomitc limestone	1,4 ton/ha or 1,8 g/vase
	Organic	Organic compound (N:1.98%)	50 ton/ha or 65 g/vase
		Gafsa Phosphate	1 ton/ha or 2,7 g/vase
		Potassium sulphate	120 kg/ha or 0,32 g/vase
		Dolomitc limestone	1,4 ton/há or 1,8 g/vase
15 after planting $N:P_2O_5:K_2O$ (40:0:0)	Conventional	Urea	90 kg/ha or 0,25 g/vase (15 days after planting)
	Organic	–––	–––

Table 2. Total phenol content (mg EAG/100 g) obtained from ethanolic extracts of organic and conventional lettuce.

System	Present study	Kapoulas et al. (2017)	Fontana et al. (2018)
Organic	301.17a	~30-40	27.4
Conventional	204.50b	~40-50	27.1

Means followed by the same letter in the column does not differ at the 5% probability level.

Table 3. FRAP (mg of quecertin/g of sample) of conventional and organic lettuce ethanolic extracts.

System	FRAP
Organic	4209.52[a]
Conventional	3553.33b

Means followed by the same letter in the column does not differ at the 5% probability level.

curve could be obtained, with excellent repeatability and linear correlation coefficient (0.995) (Figure 1).

The total phenols content were obtained from the absorbance values of the samples, using the straight line equation of analytical curve of Gallic acid. The results were expressed as mg Gallic acid equivalent per gram of sample. As seen in Table 1 the values of this study were different from those obtained by Kapoulas et al. (2017) and Fontana et al. (2018) for different lettuce cultivars.

Several studies with bran and refined flour (Mazzoncini et al., 2015), chicory (Sinkovič et al., 2015), lemons (Uckoo et al., 2015) and tomato (Watanabe et al., 2015) also showed that the organic fertilizer sources provided greater quantities of phenolic compounds.

Ferric Reducing Antioxidant Power (FRAP)

The analytical curve was constructed from the samples absorbances of trolox (Figure 2).

From the absorbance values at 595 nm and using the straight line equation of the analytical curve of trolox, the FRAO levels were obtained (Table 2). It turns out that there was a significant difference ($P < 0.05$) between the lettuces produced in both cropping systems. Lettuce produced with organic fertilizer sources presented 18.47% more antioxidant activity as against that produced with conventional sources. It was verified a significant difference ($P<0.05$) between both culture systems. Organic lettuce presented 18.47% more antioxidant activity than lettuce produced from conventional sources.

Antioxidant activity using DPPH method

The antioxidant percent (AAP%) were obtained from the samples' absorbance in different concentrations (Figures 3 and 4).

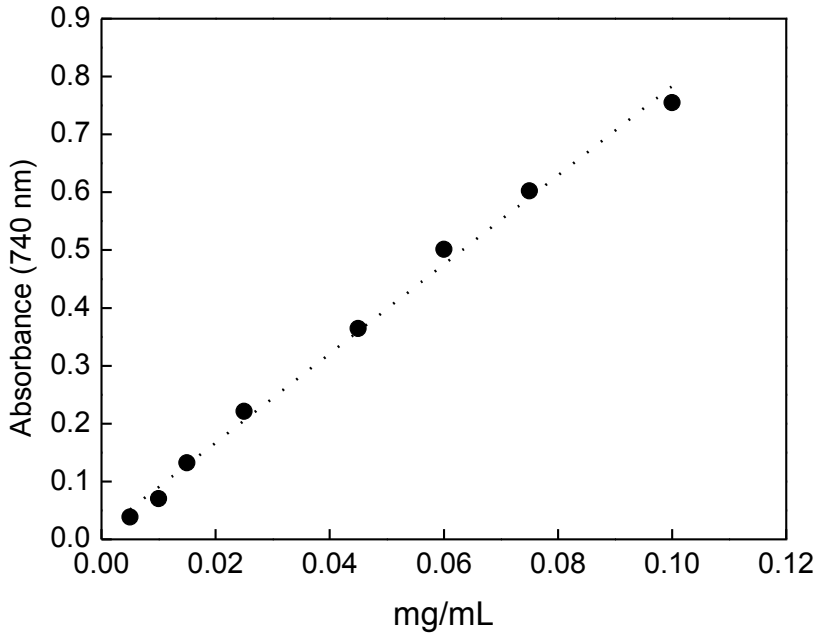

Figure 1. Analytical curve of Gallic acid.

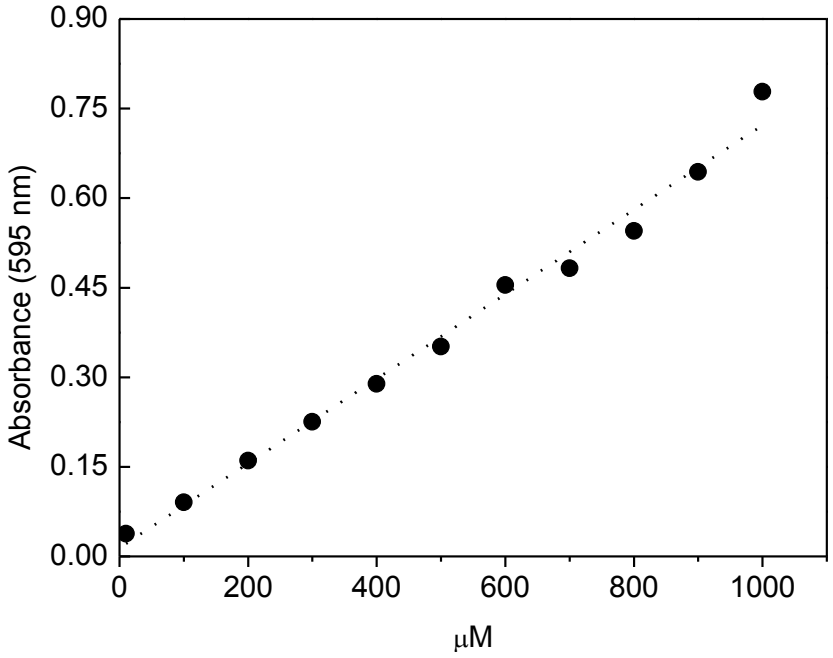

Figure 2. Analytical curve of Trolox.

The changes in the antioxidant effect of extracts depending on the concentrations, the results are presented by CE50 value, since this parameter indicates the concentration of the sample needed to promote 50% of AAP%. The lower CE50 value, the higher the antioxidant activity. From the results of absorbance of the sample, an analytical curve was constructed and through the straight line equation the CE50 was obtained. To calculate the CE50 for conventional and organic lettuce, the equation 3 and 4 were used, respectively.

$$50=0.105\times CE50+26.64 \quad (3)$$

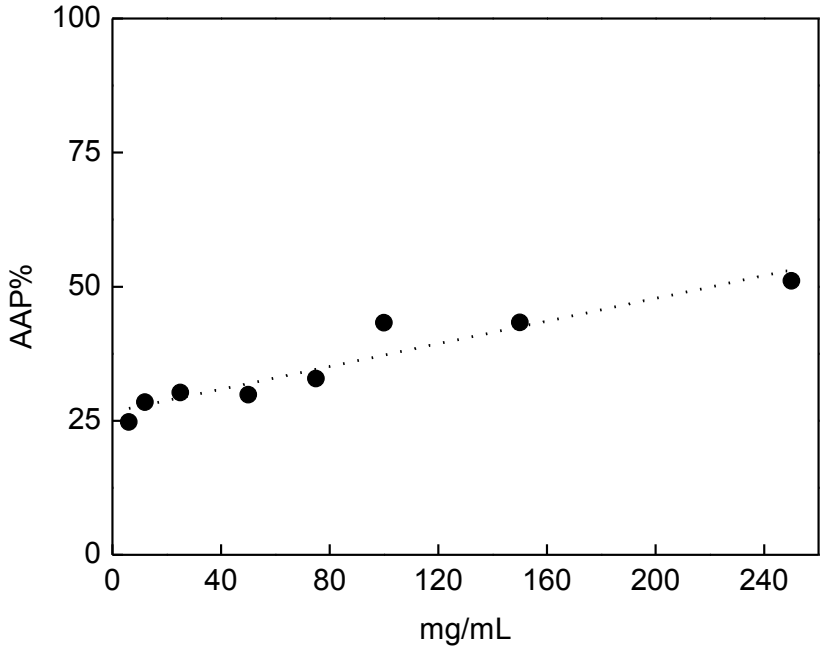

Figure 3. Antioxidant activity of conventional lettuce.

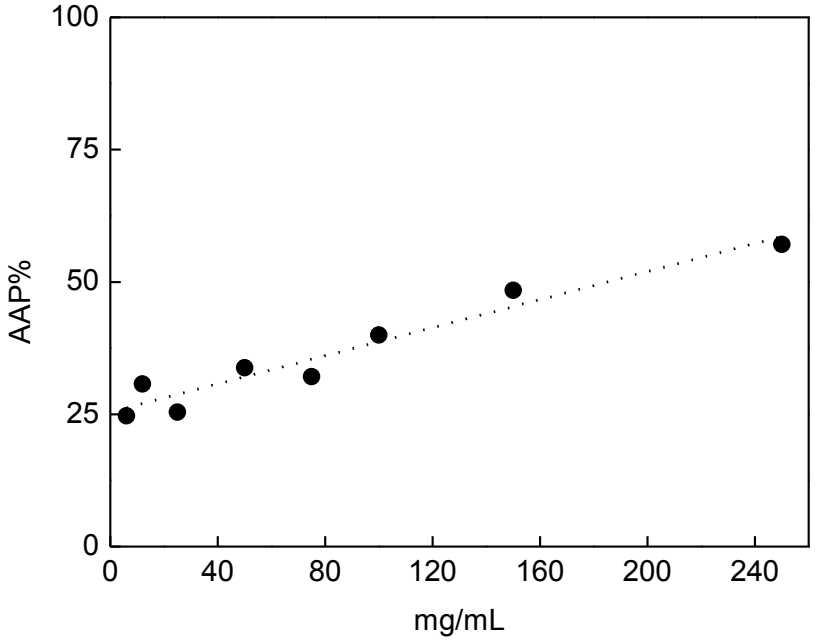

Figure 4. Antioxidant activity of organic lettuce.

$$50=0.132\times CE50+25.43 \quad (4)$$

The CE_{50} values are listed in Table 4. It was verified that the organic lettuce showed the highest antioxidant capacity (CE_{50} = 0.18 mg/mL) than the conventional lettuce (CE_{50} = 0.22 mg/mL). These results are similar to those obtained by Harsha et al. (2013) that detected 0.16 mg/mL in organic lettuce and by Kurubas et al. (2018) who found that lettuce produced in organic systems presented a higher effectiveness in antioxidant capacity

Table 4. CE50 values of organic and conventional lettuce.

System	CE50 (µg/ml)
Organic	185.14a
Conventional	220.77b

Means followed by the same letter in the column does not differ at the 5% probability level.

when compared with the conventional lettuce.

Rigueira et al. (2017) verified that the leaves and stems of collard greens cultivated in organic system had a higher antioxidant activity and levels of phenolic compounds compared to the conventional system.

The difference between these results may be due the use of different cultivars and environmental conditions where the experiments were developed. Similarly, Kim et al. (2018) found that cultivating as well as color of lettuce can change the phenol content and antioxidant activities. Therefore, the levels of phenolic compounds and antioxidant activities can change depending on the genetic material, applied management and climatic conditions used. Thus, Durazzo et al. (2014) showed the importance of cultivating, agronomic practices, edaphoclimatic, harvest and harvest season. According to the authors the variation of these elements represents the role to getting more nutritious, healthy and maximizing levels of bioactive molecules in food.

There was a better performance of organic lettuce when compared with the conventional. Comparative studies between these fertiling systems explain that the greater effects of antioxidant activity and levels of phenolic compounds are due to biotic and/or abiotic stress that plants are subjected. Baranski et al. (2014) reported that the increase of phenol content in organic lettuce it can be due to environmental stress on plants that have not received pesticides or synthetic fertilizers for your development. Sharma et al. (2017) showed that the highest content of phenolic compounds in organic brassica leaves is probably due to interference of inorganic fertilizers and pesticides with the biosynthetic role of phenolic compounds.

The biosynthesis of phenolic compounds in plants is strongly influenced by cultivar (Aires, 2016), fertilization (Medeiros et al. 2016), temperature, light and seasonal variations (Kapoulas et al., 2017; Kurubas et al., 2018). The presence of higher concentrations of polyphenols in plants could be explained by a greater absorption of phosphorus and a limited nitrogen availability (Fan et al. 2017). The discovery that organic crops have a lower N, NO_3^- and NO_2^- concentrations support the theory that differences of concentrations of antioxidants/phenolic compounds between organic and conventional crops are influenced by different nitrogen levels supply. This hypothesis is supported by previous studies that have suggested that under high nitrogen availability, plants can allocate photosynthesis carbohydrates to primary metabolism and rapid growth while producing less amounts of secondary metabolites involved in your defense (Caretto et al., 2015).

This study does not show incidence of plagues, diseases or pesticide application, thus the effects are due the sources of fertilizer used. The increased amounts of phenolic compounds and antioxidant activity are due to the gradual release of nutrients and during the development of plants.

Conclusions

Organic Lettuce had a better performance as regards phenolic compounds contents and antioxidant potential. The source of organic fertilizer is responsible for the effectiveness in antioxidant capacity and levels of phenolic compounds.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

REFERENCES

Aires A (2016). Conventional and Organic Farming-Does Organic Farming Benefit Plant Composition, Phenolic Diversity and Antioxidant Properties? Organic Farming-A Promising Way of Food Production. InTech http://dx.doi.org/10.5772/61367

Aras A, Silinsin M, Bingol MN, Bursal E (2017). Identification of bioactive polyphenolic compounds and assessment of antioxidant activity of Origanum acutidens. ILNS 66:1-8.

Baranski M, Srednicka-Tober D, Volakakis N, Seal C, Sanderson R, Stewart GB, Benbrook C, Biavati B, Markellou E, Giotis C, Gromadzka-Ostrowska J, Rembialkowska E, Skwarlo-Sonta K, Tahvonen R, Janovska D, Niggli U, Nicot P, Leifert C (2014) Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systematic literature review and meta-analyses. British Journal of Nutrition 112:794-811.

Borges LS, Vieira MCS, Vianello F, Goto R, Lima GPP (2016). Antioxidant compounds of organically and conventionally fertilized jambu (*Acmella oleracea*). Biological Agriculture and Horticulture 32:149-158.

Calado JCP, Albertão PA, de Oliveira EA, Letra MHS, Sawaya ACHF, Marcucci MC (2015) Flavonoid Contents and Antioxidant Activity in Fruit, Vegetables and Other Types of Food. Agricultural Sciences 6:426-435.

Caretto S, Linsalata V, Colella G, Mita G, Lattanzio V (2015). Carbon Fluxes between Primary Metabolism and Phenolic Pathway in Plant Tissues under Stress. International Journal of Molecular Sciences 16:26378-26394. doi:10.3390/ijms161125967

Durazzo A, Azzini E, Lazzé MC, Raguzzini A, Pizzala R, Maiani G, Palomba L, Maiani G (2014), Antioxidants in italian head lettuce (*Lactuca sativa* var. *Capitata*) grown in organic and conventional systems under greenhouse conditions. Journal of Food Biochchemistry 38:56-61.

Fan DM, Fan K, Yu CP, Lu YT, Wang XC (2017). Tea polyphenols dominate the short-term tea (*Camellia sinensis*) leaf litter decomposition. Journal of Zhejiang University-Science B. 18:99-108.

Fontana L, Rossi CA, Hubinger SZ, Ferreira MD, Spoto MHF, Sala FC, Verruma-Bernardi MR (2018). Physicochemical characterization and sensory evaluation of lettuce cultivated in three growing systems. Horticultura Brasileira 36:20-26.

Harsha SN, Anilakumar KR, Mithila MV (2013). Antioxidant properties of Lactuca sativa leaf extract involved in the protection of biomolecules.

Biomedicine and Preventive Nutrition 3(4):367-373.
Kapoulas N, Koukounaras A, Ilić ZS (2017). Nutritional quality of lettuce and onion as companion plants from organic and conventional production in north Greece. Scientia Horticulturae 219:310-318.
Kim DE, Shang X, Assefa AD, Keum YS, Saini RK (2018). Metabolite profiling of green, green/red, and red lettuce cultivars: Variation in health beneficial compounds and antioxidant potential, Food Research International 105:361-370.
Kurubas MS, Maltas AS, Dogan A, Mustafa K, Mustafa E (2018). Comparison of organically and conventionally produced Batavia type lettuce stored in modified atmosphere packaging for postharvest quality and nutritional parameters. Science Food and Agriculture https://doi.org/10.1002/jsfa.9164
Mazzoncini M, Antichi D, Silvestri N, Ciantelli G, Sgherri C (2015). Organically vs conventionally grown winter wheat: Effects on grain yield, technological quality, and on phenolic composition and antioxidant properties of bran and refined flour. Food Chemistry 175:445-451
Medeiros CH, Ribeiro LV, Custodio T, Morselli T, Sedrez F (2016). Substratos alternativos para a produção de mudas de alface. Revista Científica Rural 18:100-107.
Nimse SB, Pal D (2015). Free radicals, natural antioxidants, and their reaction mechanisms. RSC Advances 5:27986-28006.
Perez-Lopez U, Sgherri C, Miranda-Apodaca J, Micaelli F, Lacuesta M, Mena-Petite A, Quartacci MF, Muñoz-Rueda, A. (2018). Concentration of phenolic compounds is increased in lettuce grown under high light intensity and elevated CO_2. Plant Physiology and Biochemistry 123:233-241.
Reganold JP, Wachter JM (2016). Organic agriculture in the twenty-first century. Nature Plants 2(2):15221.
Rigueira GDJ, Bandeira AVM, Chagas CGO, Milagres RCRM (2017). Atividade antioxidante e teor de fenólicos em couve-manteiga (brassica oleracea l. var. acephala) submetida a diferentes sistemas de cultivo e métodos de preparo. *Semina:* Ciências Biológicas e da Saúde 37(2):3-12.
Santos J, Oliveira MBPP, Ibáñez E, Herrero M (2014). Phenolic profile evolution of different ready-to-eat baby-leaf vegetables during storage. Journal of Chromatography A 1327:118-131.
Scherer R, Godoy HT (2014). Effects of extraction methods of phenolic compounds from *Xanthium strumarium* L. and their antioxidant activity. A Revista Brasileira de Plantas Medicinais 16:41-46.
Shahidi F, Ambigaipalan P (2015). Phenolics and polyphenolics in foods, beverages and spices: Antioxidant activity and health effects – A review. Journal of Functional Foods 18:820-897.
Sharma, A, Kumar V, Kanwar MK, Thukral AK, Bhardwaj R (2017). Phytochemical profiling of the leaves of Brassica juncea L. using GC-MS. International Food Research Journal 24:547-551.
Sinkovič L, Demšar L, Žnidarčič D, Vidrih R, Hribar J, Treutter D, (2015). Phenolic profiles in leaves of chicory cultivars (*Cichorium intybus* L.) as influenced by organic and mineral fertilizers. Food Chemistry 166:507-513.
Sofo A, Lundegårdh B, Mårtensson A, Manfra M, Pepe G, Sommella E, Nisco M, Tenore GC, Campiglia P, Scopa A (2016). Different agronomic and fertilization systems affect polyphenolic profile, antioxidant capacity and mineral composition of lettuce. Scientia Horticulturae 204:106-115.
Talens P, Mora L, Bramley PM, Fraser PD (2016). Antioxidant compounds and their bioaccessibility in tomato fruit and puree obtained from a DETIOLATED-1 (DET-1) down-regulated genetically modified genotype. Food chemistry 213:735-741.
Turati F, Rossi M, Pelucchi C, Levi F, La Vecchia C (2015). Fruit and vegetables and cancer risk: A review of southern European studies. British Journal of Nutrition 113(S2):S102-S110.
Uckoo RM, Jayaprakasha GK, Patil BS (2015). Phytochemical analysis of organic and conventionally cultivated Meyer lemons (*Citrus meyeri* Tan.) during refrigerated storage. Journal of Food Composition and Analysis 42:63-70.
Watanabe M, Ohta Y, Licang S, Motoyama N, Kikuchi J (2015), Profiling contents of water-soluble metabolites and mineral nutrients to evaluate the effects of pesticides and organic and chemical fertilizers on tomato fruit quality, Food Chemistry 169:387-395.
Williams DJ, Edwards D, Pun S, Chaliha M, Burren B, Tinggi U, Sultanbawa Y (2016). Organic acids in Kakadu plum (*Terminalia ferdinandiana*): The good (ellagic), the bad (oxalic) and the uncertain (ascorbic). Food Research International 89:237-244.

Related Journals: