Journal of Root Crops, 2017, Vol. 43 No. 2, pp. 3-9
Indian Society for Root Crops
ISSN 0378-2409, ISSN 2454-9053 (online)

How Safe is Organic Cassava?

A.R. Seena Radhakrishnan and G. Suja

ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram 695 017, Kerala, India

Corresponding author: G. Suja; e-mail: sujagin@yahoo.com

Received: 20 September 2017; Accepted: 25 November 2017

Abstract

The concern for food safety, environmental issues and human health has stimulated interest in alternative agricultural systems like organic farming. Cassava (*Manihot esculenta* Crantz) is an important tropical tuber crop that plays a significant role in the food and nutritional security in rural livelihoods. Since the information on the quality of organically grown cassava tubers is meagre, a field experiment was conducted in split plot design over a period of three years at ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. The aim was to compare the tuber quality by evaluating the biochemical and mineral contents of tubers of three varieties of cassava, H-165, Sree Vijaya and Vellayani Hraswa grown under various production systems, viz., traditional, conventional, integrated and two types of organic (with or without biofertilizers). The varieties were assigned to main plots and production systems to subplots. Organic farming improved biochemical parameters by lowering the cyanogenic glucoside content (-19.60%), enhancing dry matter (+2.72%), starch (+ 8.60%), crude protein (+7.72%), sugar (+54.62%), ash (+38.42%) and fibre (+20.56%) contents. Besides, the mineral contents like P, K, Ca, Mg, Fe, Mn and Zn status of the tubers were enhanced by 1.25, 10.13, 12.89, 40.79, 59.03, 6.92 and 27.40% respectively over conventional practice in the current research. Thus, organic management in cassava produced quality and safe tubers.

Key words: Cassava, organic, conventional, dry matter, starch, crude protein, cyanogenic glucoside, mineral content

Introduction

The combined awareness of food safety and security, environmental protection, biodiversity as well as human well-being has stimulated considerable concern, favouring ecologically-grown animal and human foods (FAO, 2010; De Schutter, 2011; SCAR, 2011). The growing public concern about environmental and personal health issues have generated great consumer interest in organic farming and organically produced food (Suja et al., 2012a; Suja et al., 2012b). Consequently foods produced by organic methods are usually believed to be of superior in quality with better taste, biochemical constituents, minerals and absence of contaminants and toxic substances (Worthington, 2001; Azami et al., 2003; Perez-Lopez et al., 2007; Bimova and Pokluda, 2009).

Cassava (*Manihot esculenta* Crantz) is an important tropical tuber crop that plays a significant role in the food and nutritional security in rural livelihoods. It is one of the most important food crops in the world, after rice, wheat and maize, but ahead of potato in terms of total area planted (Howeler, 2017). Ethnic tuberous vegetables like cassava, elephant foot yam, yams etc. are preferred and are in great demand among affluent Asians and Africans living in Europe, USA and Middle East. Higher tuber quality has been documented earlier in tropical tuber crops under organic management; higher crude protein, significantly lower oxalate contents, higher K, Ca and Mg contents in elephant foot yam (Suja et al., 2012b), significantly higher Ca, slightly higher dry matter, crude protein, K and Mg contents in yams (Suja and Sreekumar, 2014) and higher dry matter, starch, sugars, P, K, Ca and Mg contents in taro (Suja et al., 2017). However, at present there is no clear scientific evidence about the impact of organic management on the tuber quality of cassava, the major tropical tuber crop. Hence the objectives were to explore the comparative advantages of organic management over conventional management on biochemical and mineral composition of cassava tubers.

Materials and Methods

Field experiments were conducted for three years (from 2011 to 2013) during June-December at ICAR-Central Tuber Crops Research Institute (CTCRI) (8°29'N, 76°57'E, 64 m altitude), Thiruvananthapuram, Kerala, India, to compare the varietal response and tuber quality under various production systems in cassava. In the land used for this study, green manure cowpea was raised and incorporated. Chemical inputs were not used for an year before taking up the current research. The soil of the experimental site was acidic (pH: 4.78) with low available N (159.94 kg ha^{-1}), high available P (163.30 kg ha^{-1}) and organic C (1.01) and medium available K (162.33 kg ha^{-1}). The site experiences a typical humid tropical climate. The mean annual rainfall was 1817 mm, maximum and minimum temperatures were 31.52°C and 24.32°C respectively and mean relative humidity was 76.50%. The experiment was laid out in split plot design with three varieties, H-165, Sree Vijaya and Vellayani Hraswa in main plots and five production systems, traditional, conventional, integrated and two types of organic in sub plots (Table 1). The gross plot size was 5.4 m x 5.4 m accommodating 16 net plants.

The crop was harvested six months after planting during the three years and the plot wise fresh samples of tubers were collected and analysed for biochemical characters like cyanogenic glucoside content (Bala Nambisan and Shanavas, 2013), dry matter, starch, total sugars (Aminoff et al., 1970), crude protein (Simpson et al., 1965), fibre and ash contents (AOAC, 2005) as per standard procedures. The mineral composition of tubers like P (Jackson, 1973), K, Ca (Piper, 1970), Mg, Fe, Mn and Zn contents (Lindsay and Norwell, 1978) were also estimated as per standard methods. The experimental data were analysed statistically using SAS (2010) by applying the technique of analysis of variance (ANOVA) for split plot design.

Results and Discussion

Biochemical composition

Cyanogenic glucoside content

The cyanogenic glucoside content varied significantly among the varieties (Table 2). Vellayani Hraswa had significantly lower cyanogenic glucoside content in the first year. However, during the second and third years, both the domestic varieties, Sree Vijaya and Vellayani Hraswa had significantly lower cyanogenic glucoside contents. Production systems imparted significant effect on cyanogenic glucoside content during the second and third years. In the first year, cyanogenic glucoside content was lowered insignificantly by 18.66% under organic management when compared to conventional practice. It is worthy to mention that organic management lowered the cyanogenic glucoside content significantly by 22.89% and 19.94% by the second and the third year respectively, when compared to conventional practice, where chemical fertilizers were used. The effect of varieties x production systems interaction was not significant during the period of study.

Averaging over the years, in the present study, organic management could lower the anti-nutritional principle, cyanogenic glucoside content in the tubers by 19.60%

Table 1. Treatment details of the experiment

Production systems	Name of inputs and quantity
Traditional (farmers' practice)	FYM @ 12.5 t ha^{-1} and ash @ 2 t ha^{-1}
Conventional (present Package of Practices (POP) Recommendations)	FYM @ 12.5 t ha^{-1} and NPK @ 100:50:100 kg ha^{-1}
Integrated	FYM @ 12.5 t ha^{-1} + NPK @ 50:25:100 kg ha^{-1} + *Azospirillum* @ 3 kg ha^{-1} and phosphobacteria @ 3 kg ha^{-1}
Organic	FYM @ 12.5 t ha^{-1}, *in situ* green manuring (normally produces green matter @ 10-15 t ha^{-1}), crop residue incorporation (generates dry biomass @ 3 t ha^{-1}) and ash @ 2 t ha^{-1}
Organic (including biofertilizers)	FYM @ 12.5 t ha^{-1}, *in situ* green manuring (normally produces green matter @ 10-15 t ha^{-1}), crop residue incorporation (generates dry biomass @ 3 t ha^{-1}) *Azospirillum* @ 3 kg ha^{-1}, phosphobacteria @ 3 kg ha^{-1} and K solubilizer @ 3 kg ha^{-1}

when compared to the conventional system, where chemical fertilizers, especially urea were used (Fig.1). Similar results of

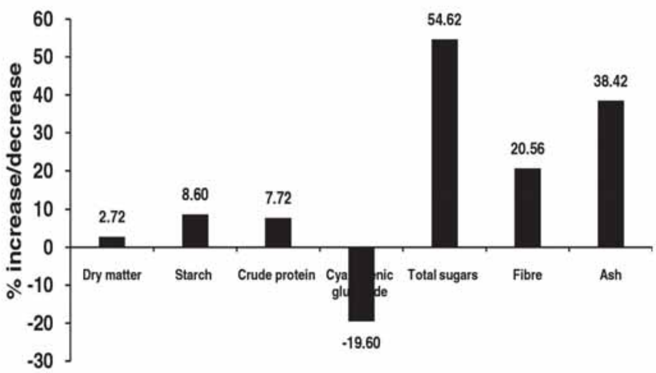

Fig.1. Per cent increase or decrease in biochemical composition of tubers under organic production of cassava over conventional practice

significant lowering of anti-nutritional principle like oxalate by 21% under organic management was reported previously by Suja et al. 2012(b) in elephant foot yam in long-term studies. The observed result in the present study is consistent with the earlier report by Omar et al. (2012) that organic fertilizer application resulted in significantly lower cyanide content compared to inorganic fertilizer and application of vermicompost resulted in higher nutritional quality in cassava. Furthermore, Omar et al. (2012) proposed that the low content of these anti-nutrients using organic fertilizer would therefore permit the absorption of these elements, which they form complexes with. Anti-nutrients are natural or synthetic compounds that interfere with the absorption of nutrients. Synthetic N fertilizer like urea might have led to faster and greater absorption of N in one stroke for storing in the N-reserve as cyanogenic glucoside, particularly when the N absorbed was in excess of that needed for the normal physiological and metabolic functions. This might have triggered the content of cyanogenic glucoside under conventional system. The comparatively slower and smaller release of N for an extended period from the organic manures used in the study, especially green manures, resulting in lower rate of N availability for crop uptake and synthesis of cyanogenic glucoside probably might have lowered its content compared to the chemical system.

Dry matter content

Varieties varied significantly in dry matter percentage during the period of experimentation (Table 2). The dry matter content of Sree Vijaya and Vellayani Hraswa was on par in the

Table 2. Effect of treatments on biochemical composition of tubers

Varieties/Production systems	Cyanogenic glucoside FW basis (μ g g^{-1})			Dry matter (%)			Starch (% FW)	Crude protein (% FW)	Total sugars (% FW)	Ash (%) FW basis	Fibre (%) FW basis
	1st year	2nd year	3rd year	1st year	2nd year	3rd year			3rd year		
Varieties											
H-165	85.00	98.50	103.20	31.56	29.75	39.16	33.53	2.69	1.26	2.38	1.21
Sree Vijaya	57.90	47.10	54.60	35.83	32.96	33.96	31.67	2.70	1.46	2.20	0.830
Vellayani Hraswa	42.10	49.80	46.60	39.33	40.26	25.50	31.54	2.67	1.51	1.72	0.606
CD (0.05)	15.25	25.100	11.020	4.187	6.694	1.038	NS	NS	NS	NS	0.105
Production systems											
Traditional	69.40	71.30	71.90	36.50	35.85	33.54	31.39	2.37	1.43	2.38	0.918
Conventional	60.00	76.10	77.20	34.59	34.42	31.94	31.51	2.59	1.19	1.90	0.827
Integrated	67.30	59.00	65.90	35.28	33.97	34.34	31.64	2.92	1.54	1.67	0.923
Organic	48.80	58.70	64.00	36.54	32.58	30.60	32.46	2.79	1.37	2.63	0.997
Organic (Biofertilizers)	62.80	60.50	61.80	34.97	34.78	33.95	34.22	2.68	1.84	1.91	0.750
CD (0.05)	NS	12.680	7.270	NS	NS	1.784	NS	NS	NS	0.457	NS

first year. Vellayani Hraswa produced significantly higher dry matter content in the second year, and H-165 proved superior in the third year. Among the production systems, significant effect was absent in the first two years. In the third year, integrated practice produced tubers with highest dry matter content on par with that of organic (with biofertilizer) and traditional treatments. Considering the average of three years, organic management led to slight increment (+2.72%) in dry matter content in cassava tubers. Higher dry matter content has been earlier documented in other tropical tuber crops like yams (Suja and Sreekumar, 2014) and taro (Suja et al., 2017) under organic management. Abu-Zahra (2016) reported that organic treatments tended to produce fruits with higher dry matter percentage over conventionally produced ones. The effect of varieties x production systems interaction was significant in the third year. Among the varieties x production systems interaction, the variety H-165 under integrated and conventional systems resulted in tubers with higher dry matter content.

Starch, crude protein, total sugar, fibre and ash contents

The starch, crude protein, total sugars and ash contents did not vary significantly among the varieties, production systems and varieties x production systems interaction (Table 2). Though the varieties did not vary significantly in starch content, the industrial variety H-165 had higher starch content, as expected. The domestic varieties, Vellayani Hraswa and Sree Vijaya had slightly higher crude protein and sugar contents. The fibre content of H-165 (1.21%) was significantly higher. Starch (+ 8.60%), crude protein (+7.72%), sugar (+54.62%), ash (+38.42%) and fibre (+20.56%) contents were higher in the organically produced tubers (with or without biofertilizers) over conventional tubers (Fig. 1). This result conforms to the earlier reports in other tropical tuber crops. Organic management enhanced the crude protein contents by 12% in elephant foot yam (Suja et al., 2012b) and 6% in yams (Suja and Sreekumar, 2014) and starch by 10.78% and sugar by 31.55% in taro (Suja et al., 2017). Abu-Zahra (2016) also found that organic treatments tended to produce fruits with higher crude fibre content over conventionally produced ones.

Mineral composition

The results of the mineral composition of the tubers estimated during the second and third years are given in Table 3. During the second year, the mineral composition of the tubers viz., P, K, Mg and Mn contents of the varieties varied significantly. The industrial variety, H-165 contained significantly higher P, Mg and Mn contents in tubers. The K content of H-165 and Sree Vijaya was on par. In the third year, though the varieties did not vary significantly, H-165 had slightly higher mineral contents in tuber.

Table 3. Effect of treatments on mineral composition of tubers (DW basis, mg $100g^{-1}$)

Varieties/Production systems	P		K		Ca		Mg		Fe		Mn		Zn	
	2nd year	3rd year	2nd year	3rd year	2nd year	3rd year	2nd year	3rd year	2nd year	3rd year	2nd year	3rd year	2nd year	3rd year
Varieties														
H-165	161.70	190.70	1250	1130	235.90	214.00	36.90	36.00	41.00	36.10	5.64	3.03	2.54	2.43
Sree Vijaya	131.40	142.10	1133	830	251.10	149.00	23.10	22.40	33.20	29.20	4.08	2.43	1.69	2.18
Vellayani Hraswa	116.70	140.10	610	666	160.10	127.00	17.60	20.00	28.80	26.90	3.42	1.96	2.54	1.55
CD (0.05)	24.95	NS	340.20	NS	NS	NS	5.83	3.00	NS	NS	0.36	NS	NS	NS
Production systems														
Traditional	127.40	202.80	849	882	203.40	217.00	30.30	30.20	42.80	34.50	4.75	2.43	1.80	2.70
Conventional	136.90	151.90	1041	923	205.50	153.00	19.50	21.20	27.10	20.50	4.28	2.22	1.77	2.39
Integrated	128.70	145.30	903	665	206.60	135.00	26.70	25.80	32.40	27.70	4.16	2.66	1.90	1.88
Organic	146.50	139.40	1137	1026	232.70	172.00	28.30	29.00	37.50	38.20	4.41	2.54	2.02	1.79
Organic (Biofertilizers)	143.60	148.80	1057	880	230.40	140.00	24.50	24.30	31.90	32.60	4.30	2.51	3.80	1.50
CD (0.05)	NS	NS	NS	215.80	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The mineral composition was not significantly influenced by the production systems, except the K content in the third year. The K content was appreciably higher in tubers produced under organic mode, which was on par with all the other treatments, except integrated. Organic management (with or without biofertilizers) could enhance the P, K, Ca, Mg, Fe, Mn and Zn status of the tubers by 1.25, 10.13, 12.89, 40.79, 59.03, 6.92 and 27.40% respectively over conventional practice in the current research (Fig. 2). The effect of the interaction between varieties and production systems was not significant.

The higher mineral content in organic crops may be due to the better availability of nutrients due to higher abundance of micro-organisms in organically managed soil. The micro-organisms produce many compounds that help plants to combine with soil minerals and make them more available to plant roots (Worthington, 2001).

Analysis of the tuber quality attributes in most years in the present study indicated that there was no significant difference in the biochemical composition and mineral content of tubers in the various production systems. This is similar to the finding of Radhakrishnan et al. (2006) that quality parameters of tea manufactured from different farming systems, including organic system, did not vary significantly. This may be due to the fact that regardless of whether the nutrients are from organic or inorganic source, plants absorb the same as inorganic ions and once absorbed the nutrients are re-synthesized into compounds that determine the quality of the produce, which is predominantly the function of genetic makeup of the plants (Chhonkar, 2008). Product quality is the complex result of a range of factors, including variety, location, fertilization and weather conditions during crop growth. However, product quality also includes the absence of harmful compounds, which is certainly determined by the management options and hence on the lower side in the organic system (Neuhoff et al., 2011).

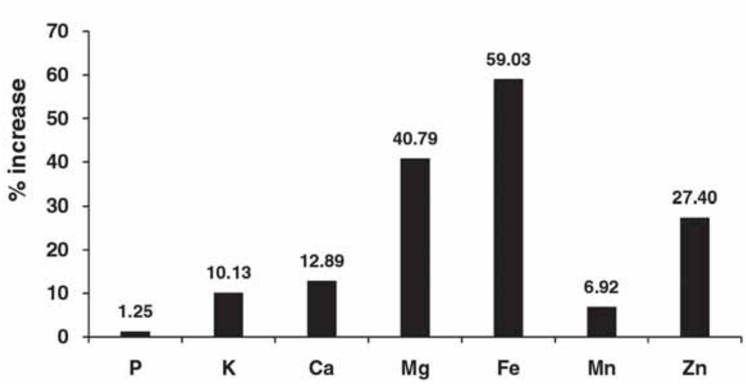

Fig.2. Per cent increase in mineral composition of tuber under organic production of cassava over conventional practice

Higher mineral content has been earlier documented in other tropical tuber crops under organic management. In elephant foot yam, organic corms had 3-7% higher K, Ca and Mg contents under organic farming (Suja et al., 2012b). Mineral content was improved with significantly higher Ca (+26%), slightly higher K (+2.40%) and Mg (+11.69%) contents in yams (Suja and Sreekumar, 2014). Cormel mineral composition was better under organic management, with higher P (+3.22%), K (1.77%), Ca (+5.52%) and Mg (+20.80%) contents in taro (Suja et al., 2017).

Well-documented studies in other crops also supports the above findings in cassava that organic cultivation can generate tubers with distinct spectrum of minerals over conventionally grown tubers. Rembialkowska (2007) stated that organic crops contain more dry matter, minerals, especially Fe, Mg and P by 21%, 29% and 14% over conventionally produced ones. Pieper and Barrett (2008) also found higher levels of K in organic tomatoes. Comparative data between organic and conventional food items indicates that organic plant products had higher dry matter and Mg contents in 310 and 162 studies conducted by AFSSA, France (2003) and FSA, UK (2009) respectively in vegetables and fruits (Lairon and Huber, 2014). Lombardo et al. (2014) observed that P, Mg and Cu were well represented in organic potatoes over conventional ones. Dvorak et al. (2016) highlighted that organic farming improved the quality characteristics of potatoes by increasing the content of polyphenols and decreasing the contents of nitrates and reducing sugars. Recent epidemiological studies advocate that under organic farming practices that use natural and safe agronomical inputs, plants can accumulate nutrients and phytochemicals, enhancing their biological value and thus increasing the nutritional quality of foods (Aires, 2016).

Conclusion

The industrial as well as domestic varieties of cassava exhibited similar performance under organic and conventional management. The study revealed the improved tuber quality of organically produced tubers over conventional tubers by reduction in the cyanogenic glucoside content, higher dry matter, starch, crude protein, sugar, fibre and ash contents and the contents of almost all minerals. Thus the study has generated new information on the safety and quality of organic cassava.

Acknowledgement

The authors gratefully acknowledge the Ministry of Environment and Forests, Government of India, New Delhi, India for the financial support and the Director, ICAR-CTCRI, Thiruvananthapuram, Kerala, India, for providing facilities for carrying out the research work.

References

Abu-Zahra, T.R. 2016. Quality and nutrient contents of fruits produced under organic conditions. In: *Organic Farming-A Promising Way of Food Production*. Petr Konvalina (Ed.). ISBN 978-983-51-4582-0, In Tech Open Science Open Minds Publishers, Croatia, Europe. pp. 353-361.

AFSSA. 2003. Report on evaluation of the nutritional and sanitary quality of organic foods (Evaluation nutritionnelle et sanitaire des aliments issus de l'agriculture biologique, in French), AFSSA, 164 pages. Accessible on line at www.anses.fr. Accessed 20 Jan 2011.

Aires, A. 2016. Conventional and organic farming-Does organic farming benefit plant composition, phenolic diversity and antioxidant properties? In: *Organic Farming-A Promising Way of Food Production*. Petr Konvalina (Ed.). ISBN 978-983-51-4582-0, In Tech Open Science Open Minds Publishers, Croatia, Europe. pp. 327-352.

Aminoff, D., Binkley, W.W., Schaffer, R. and Mowry, R.W. 1970. Analytical methods for carbohydrates. In: *The Carbohydrates*. Pigman, W. and Horton, D. (Eds). Academic Press, New York. pp. 760-761.

AOAC. 2005. *Official Methods of Analysis*, 18th Edn., Horwitz, W. and Latimer, G.W. (Eds.). AOAC International, Gaithersburg, Maryland, USA.

Azami, D.K., Hong, Y-J, Barrett, D.M. and Mitchell, A.E. 2003. Comparison of the total phenolic and ascorbic acid content of freeze dried and air-dried marionberry, strawberry and corn grown using conventional, organic and sustainable agricultural practices. *J. Agric. Food Chem.*, **51**: 1237-1241.

Bala Nambisan and Shanavas, S. 2013. Assays for Determining the Cyanide Potential of Cassava and Cassava Products. Technical Bulletin No. 54. Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India. 20 p.

Bimova, P. and Pokluda, R. 2009. Impact of organic fertilizers on total antioxidant capacity of head cabbage. *Hort. Sci.* (Prague), **36**: 21–25.

Chhonkar P.K. 2008. Organic farming and its relevance in India. In: *Organic Agriculture*. Tarafdar J.C., Tripathi K.P. and Mahesh Kumar (Eds.). Scientific Publishers, Jodhpur, India. pp.5-33

De Schutter, O. 2011. via tp://www.srfood.org/index.php/en/component/content/article/1-latestnews/1174-report-agroecology-and-the-right-to-food.

Dvorak, P., Tomasek, J., Hamouz, K. and Jedlickova, M. 2016. Potatoes. In: *Organic Farming- A Promising Way of Food Production*. Petr Konvalina (Ed.). ISBN 978-983-51-4582-0, In Tech Open Science Open Minds Publishers, Croatia, Europe. pp. 146-166.

FAO. 2010. Final Document. International scientific symposium biodiversity and sustainable diets united against hunger, 3–5 November 2010, FAO headquarters, Rome. Accessible at www.fao.org.

FSA, Food Standards Agency (UK). 2009. Comparison of composition (nutrients and other substances) of organically and conventionally produced foodstuffs: a systematic review of available literature. 31 pages. Accessible at www.food.gov.uk. Accessed 1 Sept 2009.

Howeler, R. 2017. Cassava cultivation and soil productivity. In: *Achieving Sustainable Cultivation of Cassava Volume 1 Cultivation Techniques*. Clair Hershey (Ed.). International Center for Tropical Agriculture (CIAT), Cali, Colombia. 340 p.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd.

Lairon, D. and Huber, M. 2014. Food quality and possible positive health effects of organic products. In: *Organic Farming, Prototype for Sustainable Agriculture*. Bellon, S. and Penvern, S. (Eds.). DOI 10.1007/978-94-007-7927-3_16, © Springer Science + Business Media Dordrecht, Netherlands. pp. 295-312.

Lindsay, W.L and Norwell, W.A. 1978. Development of a DTPA soil test for Zn, Fe, Mn and Cu. *J. American Soil Sci.*, **42**(3): 421-428.

Lombardo, S., Pandino, G. and Mauromicale, G. 2014. The mineral profile in organically and conventionally grown "early" crop potato tubers. *Scientia Hort.*, **167**: 169-173.

Neuhoff, D., Vlatschkov, V. and Raigon, D. 2011. Comparison of the quality of conventionally and organically grown oranges in Spain. In: *Proceedings of the 17th IFOAM Organic World Congress, Organic is Life-Knowledge for Tomorrow*. Neuhoff, D., Halsberg, N., Rasmussen, I.A., Hermansen, J., Ssekyewa, C. and Sohn, S.M. (Eds.). 28 September-1 October 2011, Republic of Korea. pp. 487-490.

Omar, N.F., Hassan, S.A., Yusoff, U.K. Abdullah, N.A.P., Wahab, P.E.M. and Sinniah, U.R. 2012. Phenolics, flavonoids, antioxidant activity and cyanogenic glycosides of organic and mineral-base fertilized cassava tubers. *Molecules*, **17**: 2378-2387.

Pérez-Lopez, A.J., López-Nicolas, J.M. and Carbonell-Barrachina, A.A. 2007. Effects of organic farming on mineral contents and aroma composition of Clemenules mandarin juice. *Eur. Food Res. Technol*., **225**: 255-260

Pieper, J.R. and Barrett. D.M. 2008. Effects of organic and conventional production systems on quality and nutritional parameters of processing tomatoes. *J. Sci. Food and Agric.*,, **89**:177-194.

Piper, C.S. 1970. *Plant and Soil Analysis*, Hans Publications, Bombay

Radhakrishnan, B., Ranjit Kumar, Q., Ganapathy, M.N.K. and Hudson, J.B. 2006. Effect of conventional, organic and biodynamic farming systems in tea. *J. Plantation Crops*, **34**: 330-333.

Rembialkowska, E. 2007. Quality of plant products from organic agriculture. *J. Sci. Food and Agric.*, **87**: 2757-2762.

SAS. 2010. SAS Users Guide. SAS Institute Inc. Cary, North Carolina, USA.

SCAR. 2011. Standing Committee on Agricultural Research of the European Committee: the 3rd SCAR Foresight Exercise 2011, Sustainable food consumption and production in a resource-constrained world

Simpson, J.E., Adair, C.R., Kohler, G.O., Dawson, E.N., Debald, H.A., Kester, E.B. and Klick, J.T. 1965. Quality Evaluation Studies of Foreign and Domestic Rices. *Tech. Bull.* No. 1331. Services, U.S.A. 86 p.

Suja, G. and Sreekumar, J. 2014. Implications of organic management on yield, tuber quality and soil health in yams in the humid tropics. *Int. J. Plant Prod*., **8**(3): 291-309.

Suja, G., Byju, G., Jyothi, A.N. Veena, S.S. and Sreekumar, J. 2017. Yield, quality and soil health under organic vs conventional farming in taro. *Scientia Hort*., **218**: 334-343, http://dx.doi.org/10.1016/j.scienta.2017.02.006.

Suja, G., Sreekumar, J., Susan John, K. and Sundaresan, S. 2012a. Organic production of tuberous vegetables: Agronomic, nutritional and economic benefits. *J. Root Crops*, **38**(2): 135–141.

Suja, G., Sundaresan, S., Susan John, K., Sreekumar, J. and Misra. R.S. 2012b. Higher yield, profit and soil quality from organic farming of elephant foot yam. *Agron. Sustain. Dev*., **32** :755–764. DOI:10.1007/s13593-011-0058-5.

Worthington, V. 2001. Nutritional quality of organic vs conventional fruits, vegetables and grains. *J. Altern Complement Med.*, **7**: 161-173.