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Comparison of Soil Parameters in Organic and Conventional Black Pepper (*Piper nigrum* L.) Cultivations in Mid Country Intermediate Zone, Sri Lanka

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Abstract

Soil physical and chemical parameters are the effective tools to evaluate long term effects of conventional and organic farming systems. The aim of this study was to compare soil fertility status of conventional and organically managed pepper cultivations in mid country intermediate zone (IM_3) in Sri Lanka. Three pairs of conventional and organically managed pepper cultivations in three different locations in IM_3 were selected. Soil samples were drawn from topsoil (0-20cm) and subsoil (20-40cm) and were analyzed for different soil parameters. Data analysis was done by two factor factorial model using statistical analysis system. Results revealed significantly higher ($p<0.05$) organic C and cation exchange capacity levels in the topsoil of organic fields compared to these values of conventional fields. However, no significant difference ($p>0.05$) in soil pH, electrical conductivity, available N, K, Ca, Mg and tested micro nutrients were reported between organic and conventional input systems in all three locations. Soil available P was significantly ($p<0.05$) higher in the topsoil of conventional fields than organic fields in all three locations. There was no significant difference ($p>0.05$) was observed in soil bulk density and porosity in both top and subsoils between organic and conventional fields. Soil N and P reported in low concentrations in all three locations can be a major yield limiting factor in both input systems. The results of the study depicted a buildup of soil organic matter and increased CEC in organically grown pepper gardens in mid country intermediate zone in Sri Lanka.

Keywords: Conventional farming, Organic farming, Pepper cultivation, Soil fertility parameters

1. Introduction

Black pepper (*Piper nigrum* L) is one of the widely used spices in all over the world. It is evergreen climbing vine and mature dried berry of this woody perennial is the economically important part. In Sri Lanka, pepper is grown as a mixed crop in the wet and intermediate zone including *Matale, Kandy, Kegalle, Ratnapura, Badulla,* and *Kurunegala* districts. The land area under pepper cultivation in Sri Lanka is about 39515 ha (Idamelkorala, *et al.*, 2018). Organic and conventional segments are the main source segments in global black pepper market. Conventional black pepper segment is covered the highest market share of 82.5% in 2016 (Global Newswire, 2018). Consumer preference of organic black pepper is increasing due to rising global trend of organic products. (Global Newswire 2018). It is fact that, conventional farming systems have contributed to soil erosion, environmental pollution, loss of indigenous crop diversity and poorer health among rural people via high inputs of synthetic fertilizer and pesticides to support high yielding. Continuous use of chemical fertilizers in conventional system negatively affects on soil health and also more fertilizer is now required to achieve similar yield due to poor soil condition (Smith 1999). Organic farming is the most appropriate way to move towards sustainability. The benefits of organic farming are not restricted to the soil health but also positively effect on human health and environment. Organic farming encourages soil fauna and flora, improving soil structure, enhance the soil nutrient and water retention ability (Reganold 1998; Stolze *et al*., 2000; Hansen *et al*., 2001; Shepherd et al., 2003). Therefore, organic farming effects positively on soil physical chemical and biological properties in soil profile . Most of the small scale pepper farmers in Sri Lanka are used less amount of fertilizer and agrochemicals to their crop. These conventional type pepper farming systems could be easily converted in to organic farming with low efforts (Gunaratne *et al.*, 2013). Maximum a three year of monitored conversion is required between the last application of chemical inputs and the sowing of the first full organic crop (Gupta, 2004). Most of the small scale pepper growers use green manure, compost and farmyard manure as organic inputs. In Sri Lanka, gliricidia is the commonly used support tree in pepper cultivations. Leaves and branches of gliricidia are directly incorporated into the soil as green manure at every pruning. According to the Department of Export Agriculture recommendation, adding 10-15 kg of gliricidia leaves per vine can easily cut down annual application of chemical fertilizer by 50% (Department of Export Agriculture, 2018). Organic manure can easily be found from the surroundings and does not pollute the environment. There are few of organic farming villages in *Matale* district, Sri Lanka under supervision of Department of Export Agriculture. Even though, many beneficial aspects of organic farming were reported, a little is known in relation to black pepper organic input systems. Therefore, this study was carried out to compare soil chemical and physical characteristics of organic and conventional pepper cultivations in mid country intermediate zone of Sri Lanka.

2. Materials and Methods

The study was carried out in pepper cultivations localized in mid country intermediate zone of Sri Lanka. Soil characteristics were analyzed in six pepper cultivations managed under organic and conventional input systems. Pepper cultivations were selected to obtain three similar pairs (organic and conventional) in same environmental conditions and same great soil group (Table 01). At the selection of locations, the requested three years' monitored conversion period was considered for organic cultivations.

2.1. Soil sampling and analysis

Soil samples were collected from the manure circle before fertilizer application in conventional fields. Soil samples were drawn from topsoil (0-20cm) and subsoil (20-40) using a gouge auger. Collected samples were air dried for 4 days and sieved through 2mm sieve before chemical analysis. Undisturbed soil samples (core samples) were taken for bulk density measurements. Physical and chemical characteristics of the soil samples were measured at Central Research Station, Deptment of Export Agriculture, *Matale*, Sri Lanka. Following standard methods were used for soil analysis (Table 02)

Table 01. Characteristics of selected locations

Locations	Farming system	Soil great group	Age of the cultivation	Land extent
Location 1 (Matale 1)	Organic*	Red Yellow Podsolic (RYP)	About 17 years	About 7 acre
	Conventional**	Red Yellow Podsolic	About 20 years	About 3 acre
Location 2 (Matale 2)	Organic	Reddish Brown Latasol (RBL)	About 10 years	About 3 acre
	Conventional	Reddish Brown Latasol	About 16 years	About 4 acre
Location 3 (Kundasale)	Organic	Immature Brown Loam (IBL)	About 08 years	About 1 acre
	Conventional	Immature Brown Loam	About 17 years	About 1 acre

***** application of organic inputs only
**application of chemical fertilizer and ago chemicals

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Table 02. Standard methods used for soil analysis

Parameter	Analytical method
pH	soil: deionized water (1: 2.5) (Rhoades 1982)
Electrical conductivity	soil: deionized water (1: 5) (Rhoades 1982)
Organic carbon	Walkley–Black method. (Nelson and Sommer 1996)
Available nitrogen	Kjeldahl method (Bremner 1960)
Available phosphorous	Olsen extraction method followed by spectrophotometry. (Olsen and Sommers 1982)
Exchangeable potassium	Ammonium acetate extraction – Flame photometer method. (Knudsen et al., 1982)
Soil CEC	Ammonium Acetate method (Chapman 1965)
Exchangeable magnesium and calcium	(Lanyon and Heald 1982).
Micronutrients (Cu, Fe, Zn, Mn)	Ammonium acetate EDTA extraction-Spectrophotometer method
Bulk density	Core sample method (Keen and Raczkowaski, 1921)

3. Results and Discussion

3.1. Soil pH and electrical conductivity

Soils in all three locations were slightly acidic in nature. The mean pH values of topsoil (0-20 cm) ranged from 6.1 to 6.4 in the organic fields where as 6.2 to 6.9 in the conventional fields. The subsoil (20-40 cm) pH values were within the range of 5.3 to 6.5 and 5.4 to 6.1 in organic and conventional fields respectively. However, no significant difference ($p \geq 0.05$) was observed in soil pH in both top and subsoils between organic and conventional pepper cultivation fields (Table 03). Nevertheless, Agegnehu *et al*., (2016) reported that adding organic matter can increase soil pH in organic pepper cultivations. Similarly, Maharjan *et al.*, (2017) also reported that soil pH was higher in established organic plots than reference in *Kavare* district, Nepal. Finding of some other studies also showed that earthworm cast presence in organic farming sites increase soil pH compared to conventional fields (Gunarathne *et al*., 2013; Reddy, 1983). Soil great groups in all three locations (RYP, RBL and IBL) were inherently acidic in reaction (Mapa *et al*., 2005). This could be the possible reason for low pH reported in both organic and conventional fields in all three locations.

Electrical conductivity (EC) measures the ability of the soil solution to conduct electricity. It serves as an indirect indicator of soluble salts in the soil. The topsoil EC values in organic locations varied between 35.2 and 40.2 μScm^{-1} whereas EC values in the conventional fields were ranged between 27.6 to 45.4 μScm^{-1}. However, soil EC values were not significantly different between two farming systems in all three locations (Table 04). According to Agriculture handbook (1954), a saline soil has an EC of the saturated paste extract of more than 4 dS/m. Since reported EC values in organic and conventional fields were very much lower than 4 dS/m, no potential risk was observed in salinity development in any of the tested location.

3.2. Soil organic matter

Soil organic matter (SOM) is considered a key attribute of soil fertility. The SOM content in the soil influences structure development, sorption and water retention in the soil. Significantly higher ($p<0.05$) SOM percentage was depicted in topsoil (0-20cm) of all three organic fields compared to that of conventional pepper fields (Table 05). This fact was because farmers used more organic inputs such as poultry manure and cattle manure in organic fields in larger quantities while that at conventional fields were very much low. Informal discussions with farmers showed that farmers used about 5 -8 t/ha of SOM per season at organic farms whereas in conventional fields, farmers apply inorganic fertilizers every year. Highest SOM percentage of 3.6 % was reported in location 01 where organic farming was started about 17 years ago, the longest period compared to other two locations (Table 01). Many studies confirmed soil SOM content increase with time under organic farming compared to conventional management (Glover *et al*, 2000; Stolze,*et al*., 2000; Shepherd, 2005) . Conventional fields also showed fairly good SOM content in the soil mainly due to continuously adding of gliricidia leaves in every pruning cycle.

3.3. Cation exchange capacity

Cation exchange capacity (CEC) is refers to the total capacity of a soil to hold exchangeable cations. It enhances soil's ability to hold onto essential plant nutrients. Soils with higher OM and clay minerals have higher CEC compared to soils with low SOM and higher sand percentage. There was a significant difference ($p<0.05$) of CEC

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between organic and conventional fields but only in topsoil in all three locations (Table 06). Highest CEC value among organic fields (14.8 $cmol_c kg^{-1}$) was observed in location 01 where highest OM percentage was reported. Similarly the lowest CEC value reported among organic fields was 11.6 $cmol_c kg^{-1}$ (location 03) which was coincide with the lowest SOM percentage. A similar relationship between SOM percentage and CEC was observed in conventional fields as well. This clearly indicated a correlation between SOM and CEC in both organic and conventional fields. The results is comparable with several other studies which showed higher CEC values in organic fields where SOM content was higher compared to conventional fields where SOM content was significantly low (Parfitt, *et al*., 1995; Reganold, 1998).

1.1.Available nitrogen, phosphorus and exchangeable potassium

Nitrogen, P and K are major essential nutrients required for plant growth. Plants cannot grow with the absence of these nutrients. Plant available fraction of these nutrients reflect fertility status of the soil. There was no significant difference ($p \geq 0.05$) observed between organic and conventional fields with respect to available N and K in both top and subsoils (Table 07&09). Nevertheless, available soil P level was significantly higher ($p<0.05$) in conventional fields (Table 08). Organic pepper farmers used green manure and farmyard manure as N, P, and K sources while inorganic pepper farmers used urea, rock phosphate and murate of potash to provide N, P and K respectively. However, farm records revealed that fertilizer application was done once in the year. Even though, urea and murate of potash contain high amount of N and K, compared to organic inputs, they are highly soluble in water and hence, highly prone to losses through leaching. The low CEC reported in conventional fields has also indicated low cation retention (NH_4^+, K^+) in the soil. This can be attributed to comparable N and K levels in both organic and conventional fields. However, low concentration of soil N was noticed in organic and conventional fields in all locations. Denitrification of nitrate cause remarkable N losses in arable lands (Simek and Hopkins, 1999). This is prominent in acidic soils and Hutsch *et al*, (2001) reported that maximum denitrification losses were observed in the range of 5.2- 5.9 of soil pH in loamy soils. Possible reason for higher P level in conventional fields could be due to adding rock phosphate once in a year. Since P releasing process is slow in rock phosphate, P losses are also in minimum level. Acidic nature of the soil may also increase the solubility of rock phosphate enhancing P availability in conventional fields. However, both organic and conventional fields had low concentration of P levels in all three locations. In contrast, K showed excess amounts in all organic and conventional fields. Therefore, at least half of the K input can be cut down especially in conventional fields to reduce annual input cost.

1.2.Calcium and magnesium

Very high concentrations of soil Ca and Mg were observed in all locations. However, both elements were not significant different ($p \geq 0.05$) between conventional and organic pepper fields (Table 10 & 11). Soil Ca varied from 257 to 284 ppm in topsoil of organic fields whereas from 218 to 287 ppm in conventional fields. Soil magnesium ranged from 217 to 355 ppm in topsoils of organic fields and from 232 to 336 ppm in conventional fields. Calcium and magnesium are two dominant cations in all great soil groups in three studied locations (Mapa *et al*, 2014). The possible reason for higher concentrations could be weathering process of calcium and magnesium rich dolomites which is available in these soils.

1.3.Soil micronutrients

Measured micronutrients in organic and conventional fields were not significantly different ($p \geq 0.05$) as shown in table 12. However, they were well within the required level for plant growth. The low soil pH reported in all three locations could be the possible reason. Most of the micronutrients tend to be more available in low soil pH because of high solubility (Brady, and Weil, 1994). Very high concentrations of Fe and Mn were observed in both input systems in all locations probably due to presence of Fe and Mn rich parent materials.

1.4 Soil bulk density

Bulk density of the soil is the ratio of soil mass to that of bulk volume of the soil. It is a highly dynamic soil property, which is a function of soil texture and soil organic matter. It affects porosity of the soil as well. Bulk density provides more accurate information about soil physical conditions. Compacted soils which have higher bulk density showed poor aeration and poor drainage. In general higher the SOM lower the bulk density of soil (Leifeld *et al*., 2005). However, in contrast to general situation, no significant difference ($p \geq 0.05$) observed in bulk density between organic and conventional fields in topsoil and subsoil (Table 13). Though organic fields had higher SOM content, conventional fields also reported better SOM content in all three locations. This can be the possible reason for comparable bulk densities observed in both input systems.

Table 03. Soil pH

Treatment	Location 1		Location 2		Location 3	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Organic	6.1[a]	5.6[a]	6.4[a]	6.5[a]	6.2[a]	5.3[a]
Conventional	6.4[a]	5.7[a]	6.2[a]	6.1[a]	6.9[a]	5.4[a]

Within columns, means followed by the same latter are not significantly difference at $p \geq 0.05$

Table 04. Soil EC (μScm^{-1})

Treatment	Location 1		Location 2		Location 3	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Organic	40.2[a]	17.3[a]	35.2[a]	19.6[a]	39.2[a]	47.0[a]
Conventional	38.3[a]	26.8[a]	45.4[a]	28.2[a]	27.6[a]	31.2[a]

Within columns, means followed by the same latter are not significantly difference at $p \geq 0.05$

Table 05. Soil organic matter (%)

Treatment	Location 1		Location 2		Location3	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Organic	3.6[a]	2.0[a]	3.1[a]	1.9[a]	2.5[a]	1.2[a]
Conventional	1.7[b]	1.8[a]	2.1[b]	1.7[a]	1.6[b]	1.1[a]

Within columns, means followed by the same latter are not significantly difference at $p \geq 0.05$

Table 06. Soil cation exchange capacity ($cmol_c kg^{-1}$)

Treatment	Location 1		Location 2		Location 3	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Organic	14.8[a]	5.9[a]	12.7[a]	7.6[a]	11.6[a]	6.2[a]
Conventional	6.9[b]	6.8[a]	8.2[b]	6.8[a]	5.5[b]	5.6[a]

Within columns, means followed by the same latter are not significantly difference at $p \geq 0.05$

Table 07. Soil available N (ppm)

Treatment	Location 1		Location 2		Location 3	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Organic	10.2[a]	8.5[a]	11.7[a]	6.4[a]	10.4[a]	4.7[a]
Conventional	15.2[a]	7.2[a]	16.3[a]	6.7[a]	12.7[a]	5.3[a]

Within columns, means followed by the same latter are not significantly difference at $p \geq 0.05$

Table 08. Soil available P (ppm)

Treatment	Location 1		Location 2		Location 3	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Organic	9.7[b]	8.2[a]	6.0[b]	4.8[a]	10.5[b]	7.2[a]
Conventional	16.4[a]	10.1[a]	12.8[a]	6.8[a]	16.6[a]	8.5[a]

Within columns, means followed by the same latter are not significantly difference at $p \geq 0.05$

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Table 09. Soil exchangeable K (ppm)

Treatment	Location 1		Location 2		Location 3	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Organic	188.3[a]	154.7[a]	163.3[a]	157.6[a]	123.6[a]	112.1[a]
Conventional	148.5[a]	136.4[a]	213.5[a]	179.8[a]	147.2[a]	122.1[a]

Within columns, means followed by the same latter are not significantly difference at $p \geq 0.05$

Table 10. Available Ca in the soil (ppm)

Treatment	Location 1		Location 2		Location 3	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Organic	262[a]	219[a]	257[a]	215[a]	284[a]	202[a]
Conventional	287[a]	217[a]	284[a]	218[a]	218[a]	196[a]

Within columns, means followed by the same latter are not significantly difference at $p \geq 0.05$

Table 11. Available Mg in the soil (ppm)

Treatment	Location 1		Location 2		Location 3	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Organic	217[a]	193[a]	355[a]	239[a]	231[a]	185[a]
Conventional	232[a]	173[a]	326[a]	247[a]	257[a]	206[b]

Within columns, means followed by the same latter are not significantly difference at $p \geq 0.05$

Table 12. Soil micronutrients (ppm)

Treatment	*Location 1*				*Location 2*				*Location 3*			
	Cu	Fe	Zn	Mn	Cu	Fe	Zn	Mn	Cu	Fe	Zn	Mn
Organic	5.6[a]	48.0[a]	6.2[a]	58.8[a]	6.5[a]	85.2[a]	4.5[a]	80.1[a]	4.9[a]	57.8[a]	1.9[a]	68.2[a]
Conventional	6.5[a]	55.3[a]	2.2[a]	57.2[a]	7.1[a]	62.6[a]	2.2[a]	80.9[a]	3.3[a]	43.2[a]	2.3[a]	56.6[a]

Within columns, means followed by the same latter are not significantly difference at $p \geq 0.05$

Table 13. Soil bulk density (gcm^{-3})

Treatment	Location 1		Location 2		Location 3	
	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil
Organic	1.34[a]	1.51[a]	1.32[a]	1.45[a]	1.35[a]	1.48[a]
Conventional	1.28[a]	1.38[a]	1.25[a]	1.51[a]	1.42[a]	1.43[a]

Within columns, means followed by the same latter are not significantly difference at $p \geq 0.05$

Table 14. Soil Texture

Treatment	**Location 1**		**Location 2**		**Location 3**	
	Top	Sub	Top	Sub	Top	Sub
Organic	SCL	SCL	SL-SCL	SCL	SL	SL
Conventional	SCL	CL	SCL	CL-C	SL	SL

3.8 Soil texture

Soil texture affects the water holding capacity, nutrient availability, cation exchange capacity, SOM availability and many other soil characteristics (Brady and Weil, 2014). Soil textural class differ from soil type to type. Texture of the location 01 was sandy clay loam in both organic and conventional fields. The reason could be the presence of red yellow podzolic soils in location 01. Soil texture of the location 02 was sandy loam to sandy clay loam probably due to reddish brown latasolic soil in the location 02. Soil texture of the location 03 was sandy loam in both top and subsoils due to presence of immature brown loam soils (Table 14). It is fact that SOM increases with increasing clay content of the soil (Prasad and Power, 1997). The reason is bonds making between clay surfaces and SOM available in the soil retard SOM decomposition process (Tisdall and Oades, 1982; Hassink *et al*., 1993). Similar to this, soils with higher clay contents in location 01 and 02 (soil texture; sandy clay loam to clay loam) reported higher SOM content compared to location 03 where clay content is comparatively low (soil texture; sandy loam).

4. Conclusions

Long term organic farming has reported increased soil organic matter content and cation exchange capacity compared to conventional black pepper cultivations in mid country intermediate zone, Sri Lanka. Deficient levels of soil nitrogen and phosphorus recorded in all studied locations can be significant yield limiting factor in both organic and conventional input systems. However, other tested nutrients in both input systems were well within the adequate range. No remarkable effect of organic farming on soil bulk density and porosity was observed in studied locations. Further studies are recommended to investigate soil microbial aspects to assess biological parameters.

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References

[1]. Administrative report (2016). Department of Export Agriculture, Peradeniya, Sri Lanka.

[2]. Agegnehu, G. Nelson, P.N. and Bird, M.I. (2016). “Crop yield, plant nutrient uptake and soil physicochemical properties under organic soil amendments and nitrogen fertilization on Nitisols,” Soil & Tillage Research, vol. 160, pp. 1–13.

[3]. Agriculture handbook (1954). Diagnosis and improvement of saline and alkali soils. United State department of Agriculture, Washington DC.

[4]. Brady, NC and Weil RR, (2014). The nature and properties of soils, *Dorling Kindersley*, India

[5]. Bremner J.M (1960). Determination of nitrogen in soil by the Kjeldahl method. The Journal of Agricultural Science. 55(1) 11:33.

[6]. Chapman, H.D. (1965) Cation Exchange Capacity. In: Black, C.A., Ed., Methods of Soil Analysis, American Society of Agronomy, Madison, 891-901.

[7]. Dahama, A. K. (1997). Organic farming for sustaining agriculture, 2nd edn. Agro Botanica press, Bikaner, India, 1-31pp.

[8]. Department of Export Agriculture (2018). Pepper shade management. www.dea.gov.lk. Retrieved on 17.08.2081.

[9]. Global newswire (2017). Persistence Market Research. Retrieved on 09 July 2018 fromwww.globalnewswire.com.

[10]. Glover J.D, Reganold J.P, Andrews P.K. (2000). Systematic method for rating soil quality of conventional, organic, and integrated apple orchards in Washington state. Agric Ecosyst Environ. 80:29–45.

[11]. Gunaratne, K. A. D. H., Karunaratne, L. M., Idamekorala, R. P. and Rohana, P. M. D. (2013). Impact of organic farming on soil properties and yield of pepper (*pepper nigrum* L). Proceedings of Annual Symposium of Minor Export Crop: Department of Export Agriculture, Peradeniya, Sri Lanka.

[12]. Gupta, M. (2004). Organic agriculture Development in India. ABD press, Rajastan, India, 58-72pp.

[13]. Hassink J., Bouwman L. A., Zwart K. B., Bloem J. and Brussard L. (1993) Relationships between soil texture, physical protection of organic matter, soil biota, and C and N mineralization in grassland soils. Geoderma 57, 105-128.

[14]. Hansen, B, Altroe, H.F, Kristensen, E.S. (2001). Approaches to assess the environmental impact of organic farming with particular regard to Denmark. Agric Ecosyst Environ. 83:11–26.

[15]. Hutsch B.W., Zhang S., Feng K., Yan F., Schubert S. (2001) Effect of pH on denitrification losses from different arable soils. In: Horst W.J. et al. (eds) Plant

Nutrition. Developments in Plant and Soil Sciences, vol 92.

[16]. Idamekorala, P.R., Heenkende, A.P., Gunaratne, H.D.A.K. and Bandara, W.M.R.S. (2018). Soil and leaf tissue nutrient status of black pepper (*piper nigrum* l.) in selected farmer's fields in Ratnapura district. Proceedings of the annual symposium of minor export crops. Department of Export Agriculture, Sri Lanka.

[17]. Keen, B.A., Raczkowski, H., (1921). The relation between clay content and certain physical properties of soil. The Journal of Agricultural Sciences 11(4): 441-449.

[18]. Knudsen, D., G.A. Peterson, and P.F. Pratt. (1982). Lithium, sodium, Sommerfeldt, T.G., C. Chang, and T. Entz. 1988. Long-term annual and potassium. p. 225–246. *In* A.L. Page et al. (ed.) Methods of manure applications increase soil organic matter and nitrogen, and soil analysis. Part 2. Chemical and microbial methods. 2nd ed. decrease carbon to nitrogen ratio. Soil Sci. Soc. Am. J. 52:Agron. Monogr. 9. ASA and SSSA, Madison, WI.

[19]. Lanyon, L.E., and W.R. Heald.(1982). Magnesium, calcium, strontium, Stivers, L.J., and C. Shennan. 1991. Meeting the nitrogen needs of and barium. p. 247–262. *In* A.L. Page et al. (ed.) Methods of soil processing tomatoes through winter cover cropping. J. Prod.analysis. Part 2. Chemical and microbial methods. 2nd ed. Agron. Agric. 4:330–335.Monogr. 9. ASA and SSSA, Madison, WI.

[20]. Leifeld J, Bassin S, Fuhrer J. (2005)_. Carbon stocks in Swiss agricultural soils predicted by land-use, soil characteristics, and altitude. Agriculture, Ecosystems & Environment.105(1-2):255-66.

[20]. Maharjan, B., Chaulagain, A., Sapkota, P., Gauchan, D.P., Lamichanne. J. (2017). Soil propertiesduring transition from conventional to organic farming system in Kavre district, Nepal. *Journal of Science, Engineering and Technology*, *Kathmandu University*,13:1, 76-84.

[21]. Mapa, R.B., Dasanayaka, A.R., Nayakakorale, H.B. (2005). Soils of the intermediate zone of Sri Lanka. Morphology, characterization and classification. Special publication No. 4. Soil science Society of Sri Lanka. Survodaya publishers, Colombo.

[22]. Nelson, D.W. and Sommer L.E. (1996). Total organic carbon and organic matter. pp. 36-404.In: Sparks, D.L. (Ed.) Method of Soil Analysis, Part 3, Chemical Methods: American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin, USA.

[23]. Olsen, S. R. and Sommers, L. E. 1982. Phosphorus. pp. 403-430. In: A. L. Page, et al. (eds.) Methods of soil analysis: Part 2. Chemical and microbiological properties. Agron. Mongr. 9. 2nd ed. ASA and SSSA, Madison, WI.

[24]. Parfitt, R.L. Giltrap, D.J. and Whitton, J.S. (1995). Contribution of organic matter and clay minerals to the cation exchange capacity of soils, *Communications in Soil Science and Plant Analysis*, 26:9-10, 1343-1355.

[25]. Prasad, R. and *Power*, J.F. (*1997*) Soil Fertility Management for Sustainable Agriculture. Lewis Publishers in an Imprint of CRC Press, 243

[26]. Raganold, P.J. (1998). Comparison of soil properties as influenced by organic and conventional farming systems. *American Journal of Alternative Agriculture*, 3:144-155pp.

[27]. Reddy, M.V. (1983). "Effects of fire on the nutrient content and microflora of casts of *Pheretima alaxandri*," in *Earthworm Ecology from Darwin to Vermiculture*, J. E. Satchell, Ed., pp. 209–213.

[28]. Rhoades, J.D. (1982). Soluble salts. p. 167–180. *In* A.L. Page et al. (ed.)mass and activity in conventional and organic farming systems. Methods of soil analysis. Part 2. Chemical and microbial methods.Soil Biol. Biochem. 30:805–816. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

[29]. Shepherd M, Pearce B, Cormack B, Philipps L, Cuttle S, Bhogal A, Costigan P, Unwin R. (2003). An assessment of the environmental impacts of organic farming. Available from: http://orgprints.org/6784/2/ OF0405_909_TRP.pdf

[30]. Simek, M., Hopkins, D. (1999). Regulation of potential denitrification by soil pH in long-term fertilized arable soils. *Biol Fertil Soils* **30,** 41–47.

[31]. Smith, T. R. (1999). Organic farming sustaining earth and people. Nawamaga press, Ratmalana, Sri Lanka, 57pp.

[32]. Stolze M. Piorr A. Haring A. Dabbert S. (2000). The environmental impacts of organic

farming in Europe. Economics and Policy 6. University of Hohenheim, Germany.

[33]. Tandon, H. L. S. (1999). Methods of Analysis of Soil, Plants, Water and Fertilizers. Fertilizer Development and Consultation Organization, New Delhi India, 144pp.

[34]. Tisdall J. M. and Oades J. M. (1982) Organic matter and water-stable aggregates in soils. Journal of Soil Science 33, 141-163.

[35]. Walter R. Campbell W.R. and Hanna, M.I. (1937). The determination of nitrogen by modified kjeldahl methodsj. Biol. Chem. 1937 119: 1.