INTEGRATED SOIL MANAGEMENT APPROACH TO ENHANCE THE GROWTH AND YIELD OF CHILLI *(Capsicum annum)*

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ABSTRACT

A field experiments were carried out at the Field Crops Research and Development Institute, Mahailluppallama (DL1b agro-ecological region) of Sri Lanka during *Maha* 2011/2012, *Yala* 2012 and *Maha* 2012/2013 seasons with the objective of identifying a package of practices which includes compost application, mulching and deep ploughing to enhance the growth and yield of chilli. The experiment consisted of two plough depths (Deep, 50-60 cm and normal, 20 cm) in the main plot, mulching at the rate of 5 t/ha (Gliricidia mulch and no mulch) and organic manure application at the rate of 10 t/ha (compost application and no compost) in sub plots. The depth to the gravel layer was at 40 cm in the tested location. Deep ploughing increased the plant performance only during the 1st season. Both, mulching with gliricidia and compost application increased plant performance. Integrated application of deep ploughing, gliricidia mulch and compost increased the plant performance only in soils having 40 cm depth to the gravel layer. In situations where deep ploughing cannot be practiced application of compost and gliricidia mulch could be recommended as viable crop management practices to enhance the growth and yield of chilli. Whenever possible, integrated application of above three management practices are recommended to enhance the growth and yield of chilli in soils having shallow depth to the gravel layer.

Keywords: Compost, Deep ploughing, Gliricidia, Mulching, Chilli

INTRODUCTION

Chilli is one of the most important cash crops grown in Sri Lanka. It is an essential ingredient in Sri Lankan meals (Kannangara *et al.*, 2013). The annual extent of chilli cultivation in 2014 is about 13,978 ha (Agstat, 2015). Though the potential yield is approximately 15 t/ha for green chilli and 3.5 t/ha for dry chilli, the national average yield in 2014 is about 5.13 t/ha and 1.01 t/ha for green chilli and dry chilli respectively (Agstat 2015). This indicates a large yield gap with a very low productivity of chilli crop. Poor management of abiotic and biotic stresses by farmers such as poor pest and disease controlling methods, non-adoption of good agronomic practices and poor management of soil are some of the neglected factors leading to lower productivity.

Soil compaction is a problem in most agricultural lands. Use of heavy machines, animals walking, frequent use of chemical fertilizers without organic manure, ploughing to a same depth continuously for many years and conducting field operations on wetter soils are responsible for the soil compaction. Compacted soil could reduce crop yields by as much as 50 % due to reduced aeration, increased resistance to root penetration, poor internal drainage and limited availability of plant nutrients (Adesigbin, 2012, Wolkowski *et al.*, 2008). The use of heavy machinery is becoming a common practice in both large farms as well as in small farmer fields in Sri Lanka. Thus, compacted soil is a problem for root growth in field crops in the Dry Zone of Sri Lanka (Kathiragamathaiya *et al.*, 1972).

Soil compaction may be corrected by deep ploughing to a depth of 50-60 cm during land preparation (Soane, 1989). Deep ploughing led to a significant increase in rooting depth, rooting density in the subsoil, water use efficiency and a yield increase of maize and wheat (Bennie *et al.*, 1986). In addition, organic matter helps to maintain or improve the physical conditions of the soil and increase the capacity for water infiltration and retention. Compost is an excellent source of organic matter and plant nutrients. It has been shown to benefit plants far beyond simply supplying them with nutrients (Terry, 2001).

Mulches are effective in weed control and conserve soil moisture. The plant-based mulches have been most effective in reducing soil temperature and improving crop-growing environment, which resulted in an increased tomato growth and fruit yield (Awodoyin *et al.*, 2007). Application of Gliricidia leaves as a mulch significantly increased the yield of both tomato and chilli under Sri Lankan conditions (Kendaragama, 1999). All these experiments on deep ploughing, organic matter addition and mulching were conducted as single factor experiments independently but the integrated effect of them has not been studied. The integrated use of above practices may further enhance the productivity of chilli, which is a major problem in Chilli cultivation in Sri Lanka.

Inherent soil physical and chemical characteristics in chill growing areas are vital for the performances of Chilli. Poor physical and chemical conditions and poor maintenance of soil moisture restricts the growth of Chilli. Integrated soil management (ISM) may help to conserve soil resources through various mechanisms such as the enhancement of soil fertility by organic and inorganic sources of nutrients, improving Carbon to Nitrogen ratio (C:N), root depth and soil biotic components while indirectly minimizing environment pollution. Therefore, this research attempted to identify a package of practices that includes organic matter application, mulching and deep ploughing to enhance the growth and yield of chilli in the Dry Zone of Sri Lanka.

MATERIALS AND METHODS

The experiments were conducted in Maha 2011/2012, *Yala* 2012 and *Maha* 2012/2013 seasons at the research fields of the Field Crops Research and Development Institute, Mahailuppallama ($8^0$06' 42.73" N and $80^0$28' 03.27" E, Elevation 117 m above mean sea level), located in the North Central province (DL1b agro-ecological region) of Sri Lanka. The soil type of the tested location is classified as Reddish Brown Earths (local) or Typic Rhodustalfs (USDA soil Taxonomy) or Rhodic Otherieutic Cutanic Luvisols (FAO classification) (Mapa *et al.*, 2010). The soil p^H and the electrical conductivity in the site were 7.2 and 0.08 ds/m. Phosphorus and Potassium contents were 12.5 ppm and 250 ppm. The bulk density was 2.14 g/cm^3 at 5-10 cm soil depth. The soil depth to the gravel layer was 40 cm.

Three soil management practices were tested in a split plot design with three replicates. They were tillage depth (main plot factor), mulching (sub plot factor 1) and compost application (sub plot factor 2). The chilli (*Capsicum annum* L) variety MI Green was used as the test crop.

Land preparation was done separately for deep ploughing block and normal ploughing block (the two main plots of 14 x 4.5 m). The normal ploughing (20 cm depth) plot was prepared using the disk plough and the deep ploug hing (50-60 cm depth) block was prepared by a backhoe machine to turn the soil up to a depth of 60 cm. Thereafter, the sub plots were prepared within the main plot. The dimensions of the sub plots were 3.2 x 4.2 m. Compost made using straw and cattle manure was applied 1 week before planting at the rate of 5 t/ha (500g/m^2) and one month after planting at a rate of 5 t/ ha (500g/m^2) to the beds of the relevant treatments and mixed well with the soil. Thirty-five days old, seedlings raised on standard field nurseries were planted in the plots at a spacing of 60 x 45 cm keeping two plants per hill. The fertilizer application was done according to the recommendations of the Department of Agriculture (Anon, 1998). Air dried Gliricidia leaves were applied as a mulch at the rate of 5 t/ha (500 g/m^2 on a dry weight basis) to the relevant treatments at one and two months after planting. For the second and third seasons, to test the long term impact of deep ploughing over seasons, experimental field was prepared using mamoties without using disk plough or backhoe machine. Thus, the land preparation treatment (deep ploughing and normal ploughing) was applied only one time during the three seasons of the experiment. The layout of treatments applied to each plot in the first season was exactly similar in the second and third season too. The rate of application of gliricidia mulch and compost was also similar to that of first season. Data were recorded on initial soil depth to the gravel layer using a soil auger, initial bulk density using a core sampler, number of pods per plant, dry chilli yield, shoot dry weight and root dry weight by obtaining the average of plants from two randomly selected planting hills and bulk density values at the end of seasons. Analysis of variance (ANOVA) was carried out using the Statistical Analysis System (SAS) (SAS institute Inc.) to identify the independent and interaction effects of depth of ploughing, mulching and compost application on growth and yield of chilli. Mean separation was done using the Tukey's Studentized Range Test.

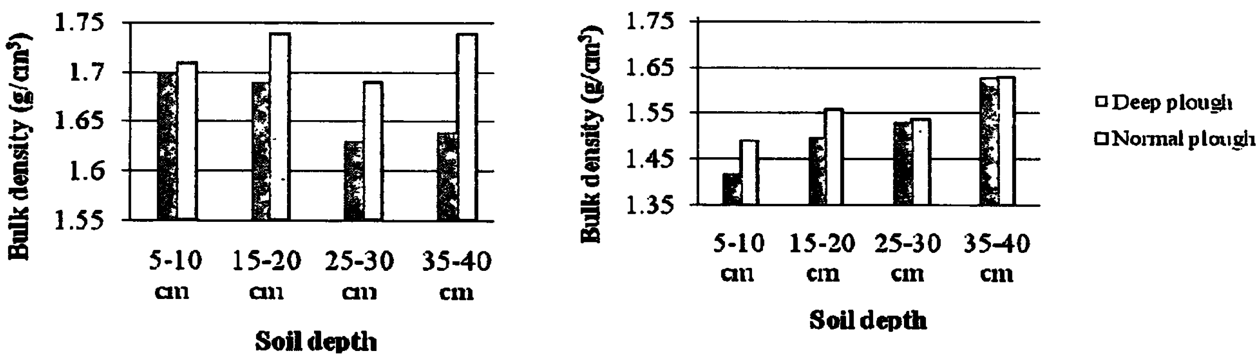
RESULTS AND DISCUSSION

Climatic data

The rainfall distribution was high in *Maha* 2012/2013 compared to *Maha* 2011/2012 season. The sunshine hours recorded during the *Maha* 2012/2013 season was lower compared to the *Maha* 2011/2012 season. Supplementary irrigation was provided during *Maha* 2011/2012 to maintain no water stress conditions. However, during the *Yala* 2012 season the rainfall was very low and due to limitation of irrigation water the crop could not continue for more than three red chilli picks.

Bulk density during the cropping period

Compared to the initial values at the site, bulk density reduced with ploughing. The bulk density values increased with the soil depth. The bulk density values of the normal ploughed treatments were high compare to the deep ploughed treatment although the effect was not different significantly (Figure 1). The bulk densities of deep ploughed plots were lower compared to the normal ploughed plots at 35 – 40 cm soil depth (Figure 1a) suggesting that the soil layer was loosened due to deep ploughing. At the end of the season, it was clearly shown that the bulk density in the top layer remained same with surface compaction due to cultural practices and surface irrigation while the layer below 25 cm had maintained lower bulk density (Figure 1a).



(a) (b)

Figure 1. Bulk density of soil (g/cm3) at the end of the *Maha* 2011/2012 (a) and *Yala* 2012 seasons (b)

The bulk density has reduced in the 2nd season both in deep ploughed and normal ploughed treatments. Although deep ploughing was not done at the commencement of the 2nd season the addition of gliricidia and compost may have contributed to reduce the bulk density values. The bulk density of the soil usually decreases by supply of organic matter from compost and resulted better drainage as well as aeration (Kluge *et al.*, 2001).

Growth and yield performances

In first two seasons (*Maha* 2011/2012 and *Yala* 2012), the shoot dry weight at the harvesting stage (120 days after planting) was significantly higher in the deep ploughed plots than the normal ploughed plots (Table 1). The effect of deep ploughing was not significantly different during the 3rd season (*Maha* 2012/2013) for the shoot dry weight. The positive impact of deep ploughing on the plant growth may have reduced with time. The similar results have been obtained in past studies on maize where deep tillage significantly increased the plant biomass in maize (Khurshid *et al.*, 2006). Deep ploughing in shallow depth soils increased the shoot dry weight. Shoot dry weight of cotton was significantly higher under deep tillage up to 50 cm depth compared to conventional (15 cm depth) and minimum tillage (7cm depth) (Ali, 2013).

In this experiment, shoot dry weight was significantly higher in the compost applied treatments during the 1st season (*Maha* 2011/2012 season) but was not significantly different in the 2nd and 3rd seasons (*Yala* 2012 season) (Table 1). The root dry weight was also significantly higher in the deep ploughed plots than the normal ploughed plots only during the 1st season (*Maha* 2011/2012 season) (Table 1). This suggests that the effect of deep ploughing was limited to one season and the impact reduced with time. The poor growth and the high CV percentage during the *Yala* 2012 and *Maha* 2012/2013 may be the reasons for not showing significant difference of the applied treatments. With the deep ploughing compact layer is broken and the roots are allowed to penetrate into deeper layers. Singh *et al.*, 2015 reported that the formation of compact layer at any depth resists the penetration of roots, its growth and development and strongly affects plant water relations of the soil. Thus, the reduction in root growth and density further decreases nutrient uptake and ultimately crop yield. Shoot dry weight, root length and root dry weight of cotton was significantly higher under deep tillage up to 50 cm depth compared to conventional (15 cm depth) and minimum tillage (7cm depth) (Ali, 2013). This indicates that plants under deep tillage encountered less soil resistance for elongation and proliferation processes when their root systems are developing. Mulching and compost application did not give a significant impact for the root dry weight.

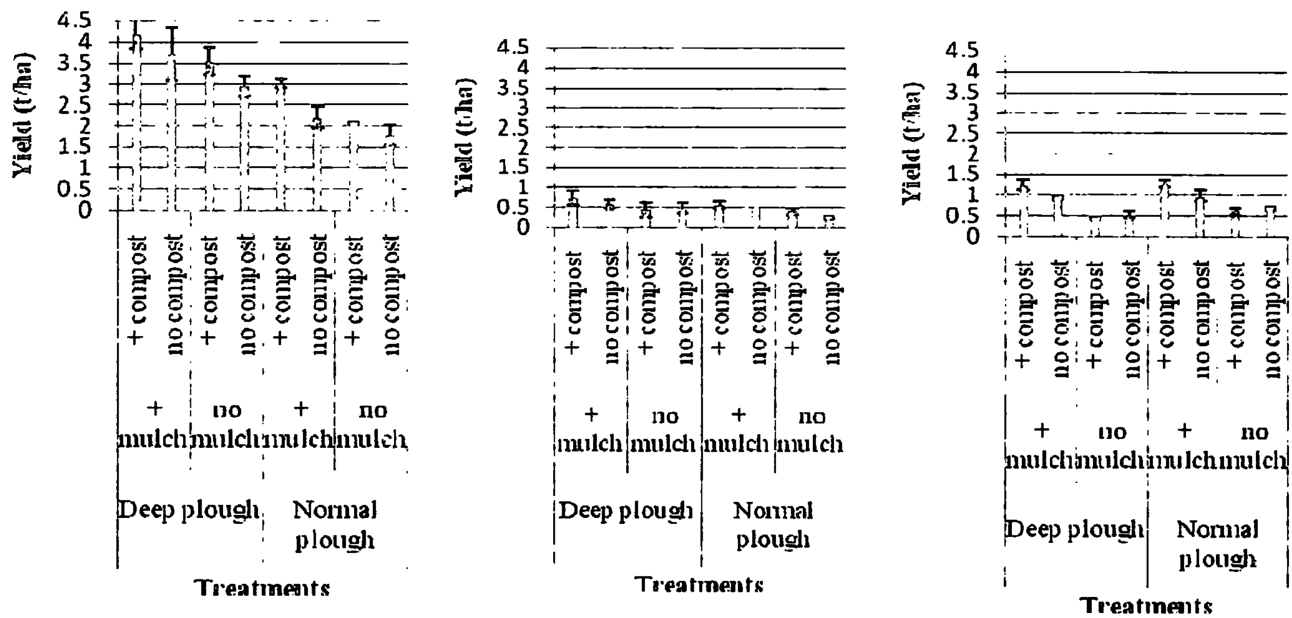
Table 1. Shoot and root dry weight (g/hill) in the *Maha* 2011/2012, *Yala* 2012 and *Maha* 2012/2013 seasons at the harvesting stage

Treatment	***Maha* 2011/2012**		***Yala* 2012**		***Maha* 2012/2013**	
	Shoot dry weight (g/hill)	**Root dry weight (g/hill)**	**Shoot dry weight (g/hill)**	**Root dry weight (g/ hill)**	**Shoot dry weight (g/hill)**	**Root dry weight (g/hill)**
Deep plough	71.6 a	13.9 a	35.7 a	6.9 a	15.3 a	4.2 a
Normal plough	38.6 b	10.5 b	21.0 b	5.7 a	12.9 a	4.1 a
Mulched	54.1 a	12.3 a	29.7 a	6.7 a	20.4 a	5.7 a
No mulch	56.2 a	12.1 a	26.9 a	5.8 a	7.9 b	2.4 b
with compost	59.6 a	13.5 a	29.7 a	6.7a	15.2 a	4.4 a
without compost	50.7 b	10.9 a	27.0 a	5.9 a	13.1 a	3.8 a
Interaction	ns	ns	ns	ns	ns	ns
CV %	11.3	20.7	12.44	18.7	33.9	22.8

Note : Values in each column followed by the same letters are not significantly different at 0.05 probability level, ns – all possible interactions are not significant

Interaction effects of the applied treatments on dry chilli yield were not significant. The integrated effects of the applied treatments showed that the total yield was significantly higher during the *Maha* 2011/2012 season having yield advantage of 136 % in the treatment where deep ploughed, compost and gliricidia mulch were applied than the control where normal ploughed and nor compost or gliricidia mulch were added. Yield in the deep ploughed plots were higher than the normal ploughed plots. However, the yield in the treatment where normal ploughing, compost and gliricidia mulch was applied was higher than the treatment where deep ploughed but gliricidia or compost was not applied. Therefore, in a situation when the deep ploughing is impossible even in the shallow depth soils application of compost and mulching with gliricidia leaves will enhance the yield by about 69% (Figure 2a).

Compared to the *Maha* 2011/2012 season the yields were very much lower during the *Yala* 2012 season as the drought conditions prevented irrigation water supply and the crop could not continue for more than three picks of red chilli. The deep ploughing effect was not shown in *yala* 2012 season and *Maha* 2012/13 season. The effect of deep ploughing was not shown in the *Maha* 2012/2013 season. The highest yield recorded in treatments where with compost and mulching during *Maha* 2012/13. Yields were higher in the treatments where mulching was done although the compost was not applied (Figure 2c). The reduction in overall yield during *Maha* 2012/13 season may be due to continuous cultivation of the same crop for three consecutive seasons.



Q *Maha* **2011/2012** (a) *Yala* **2012**(b) *Maha* **2012/2013** (c)

Figure 2. Dry chilli yield (t/ha) in *Maha* 2011/2012 season (a), in *Yala* 2012 season (b) and *Maha* 2012/2013 (c) seasons

These results are comparable with the previous studies on integrated use of poultry manure, paddy straw and coir dust together with reduced chemical fertilizer on rice. Application of poultry manure at 5 t/ha, coir dust at 5 t/ha and straw mulch at 4 t/ha combined with half the quantity of recommended chemical fertilizer proved to be the best combination to obtain significantly higher (36%) rice yield than usual nutrient management practice (Jayasundara, 2001). Number of pods per hill (Table 2) and dry chilli yield (Table 3) were significantly higher in the deep ploughed plots than the normal ploughed plots only during the *Maha* 2011/2012 season. This is because of the better growth of plants in the deep ploughed plots with more biomass. The positive impact of deep ploughing on number of pods per hill (Table 2) and dry chilli yield (Table 3) was not shown in the 2nd and 3rd seasons indicating that the effect of deep ploughing had reduced with time. Low yield and high CV percentage were some of the reasons for hiding the treatment effects during those two seasons. According to Ali (2013), deep tillage (50 cm depth) increased the cotton yield compare to the conventional (15 cm depth) and minimum tillage (7 cm depth). He concluded that deep tillage could be used successfully to improve cotton yield especially in soils affected by compaction caused by continuous use of shallow tillage implements. A study done in India with groundnut showed a significantly higher mean plot yield under annually deep ploughed plots than shallow ploughing. The deep ploughing done every alternate year and every three years were found to be the second and third best treatments for different parameters studied (Sharma *et al.*, 2014). The effectiveness of deep ploughing treatments can be prolonged by mixing organic materials or materials from the other horizons of the soil with the horizons causing problems (Unger, 1979).

Table 2. Number of pods per hill during *Maha* 2011/2012, *Yala* 2012 and *Maha* 2012/2013 seasons

	***Maha* 2011/2012**	***Yala* 2012**	***Maha* 2012/2013**
Deep plough	82 a	20 a	26 a
Normal plough	66 b	18 a	31 a
With mulch	85 a	22 a	38 a
No mulch	63 b	16 a	20 b
with compost	83 a	20 a	31 a
without compost	65 b	19 a	27 b
Interaction	ns	ns	
Mu*Com			*
CV %	13.6	39.2	18.5

Note : Values in each column followed by the same letters are not significantly different at 0.05 probability level, ns - not significant, Mu – Mulch application, Com – Compost application

Table 3. The dry chilli yield (t/ha) during *Maha* 2011/2012, *Yala* 2012 and *Maha* 2012/2013 seasons

Treatment	***Maha* 2011/2012**	***Yala* 2012**	***Maha* 2012/2013**
Deep plough	3.58 a	0.56 a	0.78 a
Normal plough	2.26 b	0.44 a	0.87 a
With mulch	3.27 a	0.61 a	1.1 a
No mulch	2.58 b	0.39 b	0.57 b
with compost	3.19 a	0.53 a	0.89 a
without compost	2.65 b	0.46 a	0.75 b
Interaction	ns	ns	
Mu*Com			*
CV %	9.32	38.6	14.78

Note : Values in each column followed by the same letters are not significantly different at 0.05 probability level, ns - not significant, Mu – Mulch application, Com – Compost application

The dry chilli yield was significantly higher in the treatments applied with gliricidia mulch than the treatments with no mulch in all three seasons (Table 3). The number of pods per hill was significantly higher in gliricidia mulch applied treatments during the 1st and 3rd seasons (*Maha* 2011/2012 and *Maha* 2012/ 2013). However, during the 2nd season (*Yala* 2012) the effect of gliricidia mulching on number of pods per hill was not significantly different (Table 2). The moisture limitation for the crop to continue and less number of picks may have affected the results during the *Yala* 2012 season. The positive effect of mulching for the yield was comparable with previous studies. Application of Gliricidia leaves as mulch significantly increased the yield of both tomato and chilli under Sri Lankan conditions (Kendaragama, 1999). Application of Gliricidia lopping as a mulch at the rate of 10 t/ha recorded significantly higher dry fruit yield in chilli (778.4 kg/ha) with compared to no mulch treatment (588.4 kg/ha) (Yadahalli, 2008). The positive impact of mulching on the yield was due to addition of organic matter from the gliricidia mulch, additional nutrients from them and moisture conservation.

The number of pods per hill (Table 2) and dry chilli (Table 3) yield were significantly higher in the treatments applied with compost than the treatments without compost during the 1st and 3rd seasons (*Maha* 2011/2012 and *Maha* 2012/2013). That is due to additional nutrients from compost and physical and biological improvement of the soil due to compost application. Application of compost at the rate of 10 t/ha and recommended levels of N, P and K fertilizers increased the number of pods per hill and dry chilli yield in the present study. Similar observations were made on several occasions with several crops by applying organic fertilizers with inorganic fertilizers. Application of bio compost (Rahman *et al.*, 2012) and poultry manure (Fariyike *et al*, 2011) increased the yield significantly in chilli while compost and farm yard manure has increased the yield of potato (Ayalew, *et al*, 2011) and yield and number of fruits per plant in sweet pepper (Malik *et al* ,2012) respectively. Application of N, P and K fertilizers and cattle manure compost and straw (De Silva *et al.*, 2005) gave satisfactory crop yields in maize and rice while cattle manure or broiler litter showed 40 % increased yield of papaw as compared to recommended N, P and K alone (Jayasundara *et al.*, 2005). The effect of compost application on number of pods per hill (Table 2) and dry chilli yield (Table

3) was not significantly different during the 2nd season (*Yala* 2012). The less number of picks obtained and high CV percentage may be the reasons for hiding the effect of compost.

CONCLUSIONS

Deep ploughing up to 50 – 60 cm depth enhanced the growth and yield of chilli in soils having shallow depth to the gravel layer. Application of compost at the rate of 10 t/ha and gliricidia mulch at the rate of 5 t/ha improved growth and yield of chilli. In situations where deep ploughing cannot be practiced in soils having shallow depth to the gravel layer, application of compost at the rate of 10 t/ha and gliricidia mulch at the rate of 5 t/ha could be recommended as viable crop management practices to enhance the growth and yield of chilli.

ACKNOWLEDGEMENTS

Authors wish to thank the Director, Additional Director and Deputy Director of FCRDI at Mahailluppallama, Sri Lanka for their encouragement and providing facilities to carry out this experiment.

REFERENCES

Adesigbin A. J. and Fasinmirin J. T. 2012. Soil Physical Properties and Hydraulic Conductivity of Compacted Sandy Clay Loam Planted with Maize *Zea mays*.In: O. Martins, E. A. Meshida,T. A. Arowolo, O. A. Idowu and G. O. Oluwasanya (Eds.), Proceedings of the Environmental Management Conference, September 12 -15, 2011, Federal University of Agriculture, Abeokuta, Nigeria. Vol. 1: 2 – 21 [on line] [Accessed on 9 August 2013] Available at http://www.unaab.edu.ng/attachments/volume2.pdf

Ali, S.A.M. 2013. Effect of Tillage on Soil Properties and Cotton (Gossypium Barbadence L) Yield in Sudan Gezira. ARPN Journal of Science and Technology. Vol. 3. Pp 928-934.

Anon. 1998. Crop recommendations techno guide. Department of Agriculture. Peradeniya. Pp 141-145.

Anon. 2012. Soil compaction. Soil themes. Land management and natural hazards unit. European commission. Joint Research Centre. Institute of environment and sustainability. on line] [Accessed on 8 August 2013] Available at http://eusoils.jrc.ec.europa.eu/library/themes/compaction/

Agstat, 2015. Pocket book of Agricultural statistics. Vol XII. Department of Agriculture, Peradeniya, Sri Lanka.

Awodoyin, R.O., Ogbeide, F.I. and Oluwole, O., 2007. Effects of Three Mulch Types on the Growth and Yield of Tomato (*Lycopersicon esculentum* Mill.) and Weed Suppression in Ibadan, Rainforest-savanna Transi-tion Zone of Nigeria. . [on line] [Accessed on 10 August 2013] Available at www.sljol.info/index.php/TARE/article/download/1871/1562

Ayalew, A. and Dejene, T. 2011. Integrated Application of Compost and Inorganic Fertilizers for Production of Potato (*Solanum tuberosum* l.) at Angacha and Kokate in Southern Ethiopia. Journal of Biology. Agriculture and Healthcare. Vol. 1, No.1. pp15-24. [on line] [Accessed on 5 October 2013] http://www.academia.edu/1292090/Integrated_Application_of_Compost_and_Inorganic_Fertilizers_for_Production_of_Potato

Bennie, A.T.P. and Botha, F.J.P. 1986. Effect of deep tillage and controlled traffic on root growth, water-use efficiency and yield of irrigated maize and wheat. Soil and tillage research. Vol.7. Pp.85-95

De Silva, S.H.S.A., Chandrapala, A.G. and Jayalath, H.A.P. 2005. Evaluation of different organic manures on soil properties growth and yield of rice and maize under rice / maize crop rotation. Annals of the Sri Lanka Department of Agriculture. Vol 7. Pp 87-94.

Fariyike, A.T., Adebeyo, O.S., Akinwumi, G.S., Ademoyegum, O.T., Akinpelu, C.A. and Adesegun, E.A. 2011. Evaluation of growth and yield of (*Capsicum annum* L.) var

'Nsukka Yellow' under different fertilizer regimes in Ibadan, South – Western Nigeria. The African Journal of Plant Science and Biotechnology. 5(1), Pp 46-49.

Jayasundara, J.M.P.B. 2001. Effect of integrated application of organic and chemical fertilizer on dry seeded rice (*Oryza sativa* L.). Annals of the Sri Lanka Department of Agriculture. 3 : Pp 61-70.

Jayasundara, J.M.P.B. and Huruggamuwa, H.M.N.K. 2005. Effect of organic and chemical fertilizer on growth, yield and fruit quality of papaw. Annals of the Sri Lanka Department of Agriculture. Vol 7. Pp 103-110.

Kannangara. K.N and Karunathilake, K.E. 2013. Chilli cultivation (Sinhala). Department of Agriculture. Peradeniya.

Kathiragamathaiya, S. and Nagarajah, S. 1972. Effect of soil compaction due to leveling on the growth and development of maize on RBE soils. Tropical Agriculturist Vol. cxxviii;1. Pp 4-26.

Kendaragama, K.M.A., 1999. Response of tomato and chilli to application of four organic materials on an Alfisol. Proceedings of the Annual Symposium of the Department of Agriculture Pp 101-107.

Khurshid, K., Iqbal, M., Arif, M.S. and Nawaz, A., 2006. Effect of tillage and mulch on soil physical properties and growth of maize. International Journal of Agriculture Biology. Vol.8, No. 5. Pp 593-596. Institute of Soil and Environmental Sciences. University of Agriculture. [on line] [Accessed on 8 August 2013] http://www.fspublishers.org/published_papers/5034_..pdf

Kluge, R. and Bolduan, R. 2001. Several years application of compost – effects on physical and microbiological properties of soils. Applying compost, benefits and needs. Seminar proceedings. Brussels. Pp. 225-228

Mahmoud, E., Kader, N.A.E., Robin, P., Corfini, N.A. and Rahman, L.A.E., 2009. Effects of Different Organic and Inorganic Fertilizers on Cucumber Yield and Some Soil Properties. World Journal of Agricultural Sciences 5 (4): 408-414

Malik, A.A., Chattoo, M.A., Sheemar, G. and Rashid , R. 2011. Growth, yield and fruit quality of sweet pepper hybrid SHSP – 5 (*Capsicum annuum* L.) as affected by integration of inorganic fertilizers and organic manures (FYM). Journal of Agricultural Technology 7(4):1037 -1048

Mapa, R.B., Somasiri, S. and Dassanayake, A.R. 2010. Soils of the Dry Zone of Sri Lanka. Special publication no.7. Soil Science Society of Sri Lanka. Pp. 95

Rahman, M.A., Rahman, M.M., Begum, M.F. and Alam, M.F. 2012. Effect of bio compost, cow dung compost and NPK fertilizers on growth, yield and yield components of chili. International Journal of Biosciences. Vol. 2. Pp 51-55.

Singh, J., Salaria, A. and Kaul, A. 2015. Impact of soil compaction on soil physical properties and root growth: A review. International Journal of Food, Agriculture and Veterinary Sciences. Vol. 5 (1) , pp. 23-32

Sharma, G., Maruthi Sankar, G., Akbari, K., Sreenivas Reddy, K., and Sutaria, G. 2014. Efficient Tillage Practice for Maximum Infiltration, Rainwater Use Efficiency, and Profitability from Groundnuts under Semiarid Vertisols in Western India. *J. Irrig. Drain Eng.*, 140(3), 04013019

Soane, B.D., 1990, The role of organicmatter in soil compactibility: Areview of some practicalaspects. Soil and tillage research. Vol 16: 1-2. P 179-201. From http://www.sciencedirect.com/science/article/pii/016719879090029D

Terry, E. P., 2001. Soil organic matter.Maryland cooperative extension. University of Maryland. [on line] [Accessed on 10 August 2013] Available at http://extension.umd.edu/publications/pdfs/fs783.pdf

Unger, P.W., 1979. Effects of deep tillage and profile modification on soil properties, root length and crop yields in the United States and Canada. Elsevier Scientific Publishing Company, Amsterdam, Netherlands. Pp 275-295.

Wolkowski R., Lowery B. 2008. Soil compaction, causes, concerns and cures. University of Wisconsin – Extension. [on line] [Accessed on 8 August 2013] Available at http://www.soils.wisc.edu/extension/pubs/A3367.pdf

Yadahalli V. 2008. Studies on the effect of mulches, organics and organic solutions on growth, yield and quality of chilli (*Capsicum annum* L.) cv. Byadagi Dabbi in Northern transition zone at Karnataka, A thesis, Department of Agronomy, College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad.