ISSN (Online): 2349-1183; ISSN (Print): 2349-9265
TROPICAL PLANT RESEARCH
The Journal of the Society for Tropical Plant Research

5(3): 286–291, 2018
DOI: 10.22271/tpr.2018.v5.i3.036

Research article

Determination of nutrients and fiber contents of seven invasive plants and their decomposition rates

N. Hewavitharana[1]*, S. D. P. Kannangara[1], L. R. Jayasekera[1] and P. Weerasinghe[2]

[1]Department of Botany, Faculty of Science, University of Kelaniya, Sri Lanka
[2]Horticultural Crop Research and Development Institute (HORDI), Gannoruwa, Sri Lanka

*Corresponding Author: nalakahewavitharana@gmail.com [Accepted: 22 October 2018]

Abstract: Nutrients (C, N, P, K, Mg, Ca, Cu, Fe Mn and Zn), fiber contents and decomposition rates of seven invasive plants (*Mikania scandens, Tithonia diversifolia, Lantana camara, Sphagneticola trilobata, Chromolaena odorata, Mimosa pigra* and *Panicum maximum*) were analyzed aiming at their potentiality to prepare cost effective, organic compost for crop cultivation. Litter bag technique was used to measure the decomposition rates. Significantly the highest nutrient contents; N (3.44%), Mg (1.3%), Cu (34 mg kg^{-1}), Fe (393 mg kg^{-1}), Mn (150 mg kg^{-1}) and Zn (671 mg kg^{-1}) were found in *M. scandens*. *T. diversifolia* had significantly higher P (0.37%) and Ca (4.92%) contents than that of others. *S. trilobata* showed significantly higher K content (4.32%). Whereas, *M. scandens* and *T. diversifolia* showed significantly lower organic carbon contents (16.8% and 19.8%), crude fiber contents (4.85% and 3.50%) and C:N ratio (4.8 and 6.1) respectively. Significantly higher decomposition rates were observed in *M. scandens* (k= 12.91 per year) and *T. diversifolia* (k= 10.77 per year). Although the nutrient contents and decomposition rate (k= 3.41 per year) in *P. maximum* were significantly lower, but its carbon (33.7%), crude fiber content (20.42%) and C:N ratio (26.5) were significantly higher than that of others. *T. diversifolia* and *M. scandens* have the potential to use in low cost organic compost preparation, due to their comparatively higher nutrients and decomposition rates. *P.maximum* can also be incorporated in preparing compost for its higher crude fiber content to improve the soil physical properties.

Keywords: Nutrients - Crude fiber - Invasive plants - Decomposition.

[Cite as: Hewavitharana N, Kannangara SDP, Jayasekera LR & Weerasinghe P (2018) Determination of nutrients and fiber contents of seven invasive plants and their decomposition rates. *Tropical Plant Research* 5(3): 286–291]

INTRODUCTION

Sri Lanka is a tropical country with invasive plants distributed all over the country. At present limited information is available on the distribution and abundance of invasive plant species in many areas of Sri Lanka (Weerakoon 2008). Invasive plants alter ecosystem functions, reduce profitability, productivity long term sustainability of agriculture and national resources. (Veeragurunthan 2009). Even though, these invasive plants are problematic, some of them have the potential to be utilized as green manure based on their nutrient compositions. Preparation of the composts by using these plants; and it would be a possible way to manage invasive plants by sustainable manner. It is important to know the nutrient status, rate of decomposition, abundance and growth rates of these plants for better selection.

Organic farming is important now a day because of the residual effect of chemicals (fertilizers and substances) used in agriculture leading the environmental pollution and human health as well (Hsieh *et al.* 1996). Therefore researchers showed considerable interest in promoting the use of green manures in crop cultivation. Many plant species have the ability to serve as good organic manure and the addition of such plants to the field can enhance soil fertility (Akanbi *et al.* 2007).

In the central region of Sri Lanka, use of green leaves and twigs of certain common trees and plants, such as Kekuna (*Canarium zeylanicum* (Retz.) Blume), Dadap (*Erythrina variegata* L.), Keppetiya (*Croton laccifer* L.),

Received: 20 May 2018 Published online: 31 October 2018
https://doi.org/10.22271/tpr.2018.v5.i3.036

Karanda (*Pongamia pinnata* (L.) Pierre) and wild sunflower (*Tithonia diversifolia* (Hemsl.) A.Gray) as green manure is a common practice in rice cultivation (Sangakkara *et al.* 2004). In addition, *Sesbania* spp. and *Crotalaria* spp. have the highest nitrogen contents and the lowest C:N ratios among the species that exhibit wide spread distribution in Sri Lanka (Weerakoon 2008).

The amount of nutrients contributed by green manure will depend on the chemical composition of plant parts and the amount added (Sariyildiz & Anderson 2003). However, many researchers have indicated that a significant increase of total soil nitrogen, available phosphorus exchangeable potassium, magnesium content and soil organic carbon with the application of green manure (Jama *et al.* 2000, Akanbi *et al.* 2005, Nziguheba *et al.* 2005, Olabode *et al*. 2007, Shokalu *et al.* 2010). Although many studies (Alexander 1977, Swift *et al.* 1979, Johansson 1995) have been carried out to investigate the effects of leaf quality variables on decomposition using different plant species, but best indicator of leaf variable for the decomposition is still unknown. The objectives of the present study were to determine the leaf chemical composition of selected widely available invasive plant species and to investigate their decomposition rates.

MATERIALS AND METHOD

Collection of invasive plants

Leaf samples of *Mikania scandens* (L.) Willd., *Tithonia diversifolia* (Hemsl.) A.Gray, *Lantana camara* L., *Sphagneticola trilobata* (L.) Pruski, *Chromolaena odorata* (L.) R.M.King & H.Rob., *Mimosa pigra* L. and *Panicum maximum* Jacq. (Table 1) were collected from Madawachchiya, Nikaweratiya, Ulapane, Horana and Godagama areas of Sri Lanka. Three replicate of leaf samples from each site was collected separately in polythene bags and transported to the laboratory in University of Kelaniya. Sri Lanka.

Table 1. Selected invasive plants (with their family and common names) in Sri Lanka.

S.N.	Plant species	Family	Common name
1	*Mikania scandens* (L.) Willd.	Asteraceae	Watupalu
2	*Tithonia diversifolia* (Hemsl.) A.Gray	Asteraceae	Naththasuriya
3	*Lantana camara* L.	Verbenaceae	Gandapaana
4	*Sphagneticola trilobata* (L.) Pruski	Asteraceae	Arunadevi/Kaha karabu
5	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Asteraceae	Podisinghomarang
6	*Mimosa pigra* L.	Fabaceae	Yodha nidikumba
7	*Panicum maximum* Jacq.	Poaceae	Gini thana

Samples preparation

Sample were washed properly in running tap water followed by rinsing in distilled water, air dried at room temperature (30°C) for two days and oven dried at 80°C until a constant weight was obtained. The oven dried samples were ground using a mortar and pestle and were sieved using a 2 mm mesh. The homogenized leaf samples were transferred to clean glass bottles and stored at room temperature.

Determination of nutrients contents

Nutrients and fiber contents of invasive plants were analyzed at the Horticultural Research and Development Institute (HORDI) in Gannoruwa and at CIC Soil, Plant and Water Analytical Laboratory in Dambulla. Organic carbon contents were determined by Walkley- Black method (Walkley & Black 1934). The total nitrogen (N) and phosphorus (P) contents were determined by Kjeldahl (Kjeldahl 1883) and Vanado-molybdate method (Bernhart & Wreath 1955). Contents of potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) were determined on a dry weight basis by atomic absorption spectrophotometry (Model: Spectraa 110) following a wet digestion with a tri acid mixture (HNO_3:H_2SO_4:$HClO_4$; 9:4:1) at 200°C (Jackson 1973). A blank solution was prepared with tri acid mixture without adding samples. Crude fiber contents were determined gravimetrically after chemical digestion and solubilization of the materials following Weende method (AOAC 1990).

Rate of decomposition

Litter bag technique was used to determine the decomposition rates of the selected invasive plants in order to identify fast decomposition species. Fresh leaves of the seven invasive plants were washed properly in running tap water and rinsed in distilled water then air dried. Five grams of the air-dried leaves of each plant species was placed in 1 mm mesh litter bags (20 × 20 cm). They were randomly placed on the ground in the Botanical Garden (6° 58.428' N, 79° 54.851' E) University of Kelaniya. The precipitation is it affects more or less similarity to the decomposition of all the litter materials. The average soil depth is 15 cm and the stagnant water has been always drained out naturally from the study site. Physiochemical properties of study site was studied.

Soil was sandy clay loam in texture, having a moderate drainage and pH range of 5.5–6.0. Microbial activities was relatively low. The mean annual precipitation is 2400 mm, with 50–75 mm per month during the dry season of experiment period (January to April). Average monthly temperature ranges 28–32°C and relative humidity is 65%. Forty replicates were used per plant species. Five litter bags of each leaf species were randomly collected in every 2 weeks and roots, adhering soil particles were removed gently without damaging the litter materials inside. Leaf residues were oven dried at 70°C for a constant weight was obtained. Finally the percentage of mass remaining was calculated using following equation and then % of mass remaining was plotted at intervals of two weeks **(**Guendehou *et al*. 2014).

$$\%\text{ of Mass remaining } = \frac{\text{Mass after } 70^{o}\text{C dried}}{\text{Mass of sample (5 g)}} \times 100$$

Data analysis

Data obtained were analyzed statistically with the MINITAB version 16 using one-way analysis of variance (ANOVA, $p < 0.05$) followed by Tukey's pair-wise multiple comparison test to determine whether the nutrient content of the 7 plant species were significantly different.

Single negative exponential decay model (Hartemink & Sullivan 2001) applied in decomposition studies was fitted to the observations on remaining mass in the seven invasive plant species studied using following equation (Loranger *et al*. 2002).

$$Y = e^{-k \times t}$$

$$Y = X_t / X_0$$

Where Y is the proportion initial leaf mass remaining at time t and k is the decomposition factor. X_t is the remaining mass of the litter at time t, X_0 the initial mass of the leaf placed in the litter bags. The linear regression of the lnY vs. time (t) was further done for the calculation of k value.

RESULTS AND DISCUSSION

Nutrients and fiber contents of the invasive plants

According to the results of nutrient analysis, *Mikania scandens* and *Tithonia diversifolia* exhibited comparatively higher macro nutrient contents compared to that in the others (Table 2). However, *M. scandens* and *T. diversifolia* had a significantly lower amount of organic carbon (16.8%; 18.7%) and fiber content (3.5%; 4.8%) compared to *Panicum maximum* (20.4 %). *P. maximum* had the highest carbon (33.7%) and fiber content (20.4%), but lower in other nutrient contents (N; 1.27%, P; 0.24%, Ca; 1.55% and Mg; 0.54%). The C/N ratio *M. scandens* (4.8) and *T. diversifolia* (6.1) were significantly lower than that of the other plant species studied ($p < 0.05$).

Table 2. Macro nutrient and fiber contents (%) of selected invasive plants.

Plant species	C%	N%	P%	K%	Ca%	Mg%	Fiber %	C:N
Mikania scandens	16.8^{c}	3.44^{a}	0.36^{a}	3.30^{a}	3.39^{a}	1.33^{a}	3.5^{c}	4.8^{c}
Tithonia diversifolia	19.8^{c}	3.28^{a}	0.37^{a}	2.53^{b}	4.92^{a}	0.83^{ab}	4.8^{c}	6.1^{bc}
Lantana camara	21.3^{cb}	2.51^{ab}	0.28^{a}	1.90^{b}	3.85^{a}	0.64^{b}	10.6^{ab}	8.4^{b}
Sphagneticola trilobata	23.5^{cb}	2.15^{ab}	0.32^{a}	4.32^{a}	2.81^{b}	0.57^{b}	10.2^{b}	10.9^{b}
Chromolaena odorata	20.2^{cb}	2.94^{ab}	0.28^{a}	1.62^{b}	3.49^{a}	0.92^{a}	8.7^{b}	6.9^{b}
Mimosa pigra	30.6^{ab}	2.98^{ab}	0.23^{b}	0.29^{bc}	3.08^{a}	0.47^{b}	15.2^{ab}	10.7^{b}
Panicum maximum	33.7^{ab}	1.27^{cb}	0.24^{b}	1.44^{b}	1.55^{c}	0.54^{b}	20.4^{a}	26.5^{a}

Note: Each data point represents the mean of ten replicates. Means sharing a common letter (s) in each column are not significantly different $p > 0.05$ by Tukey's multiple comparison test.

The highest N and Mg contents were observed in *M. scandens* (3.44% and 1.33% respectively); and the lowest N (1.27%) and Mg (0.47%) contents were observed in *P. maximum* and *Mimosa pigra* plant leaves respectively. The highest K content (4.32%) was found in *Sphagneticola trilobata* while *M. pigra* had the lowest (0.29%). The highest P (0.37%) and Ca (4.92%) contents were found in *T. diversifolia* whereas the lowest P (0.23%) and Ca (1.55%) contents were found in *M. pigra* and *P. maximum* respectively (Table 2). *M. scandens* had the highest Cu (34 mg kg^{-1}), Fe (393 mg kg^{-1}), Mn (150 mg kg^{-1}) and Zn (671 mg kg^{-1}) contents. The lowest Cu content was found in *P. maximum* (9 mg kg^{-1}) while the lowest Fe (76 mg kg^{-1}), Mn (70 mg kg^{-1}) and Zn (267 mg kg^{-1}) contents were detected in *S. trilobata*, *T. diversifolia* and *P. maximum* respectively (Table 3).

Olabode *et al.* (2007) found 1.76%, 0.82%, 3.907%, 0.005% and 5.53% of N, P, K, Ca, Mg and crude fiber respectively in *T. diversifolia* and 1.12%, 1.62%, 1.49%, 1.42%, 0.205% and 17.30% respectively in *P.*

maximum. Agbede *et al*. (2013) reported the chemical composition of *T .diversifolia* as C (4.8 %), N (1.88%), P (0.79%), K (3.89%), Ca (3.41%) and Mg (0.004%). The nitrogen content for *T. diversifolia* in the present study was significantly higher than the values reported by Agbede *et al*. (2013). Sariyildiz & Anderson (2003) and Reddy & Venkataiah (1989) were also reported that the nutrient content in green manure varies with the age of the plants, soil fertility, climatic conditions, season and proportion of the leaf to stem. However, Jama *et al.* (2000) reported more or less similar values for N (3.50%), P (0.37%) and K (4.10%) contents of *T. diversifolia* in comparison to the present study.

Table 3. Some micro nutrient contents (mg kg^{-1}) of selected invasive plants.

Plant species	Cu (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})
Mikania scandens	34^{a}	393^{a}	150^{a}	671^{a}
Tithonia diversifolia	10^{b}	296^{ab}	70^{b}	517^{a}
Lantana camara	10^{b}	285^{ab}	118^{a}	365^{b}
Sphagneticola trilobata	24^{a}	76^{c}	130^{a}	510^{a}
Chromolaena odorata	19^{b}	375^{a}	77^{b}	363^{b}
Mimosa pigra	10^{b}	172^{c}	136^{a}	394^{b}
Panicum maximum	9^{b}	181^{c}	72^{b}	267^{b}

Note: Each data point represents the mean of ten replicates. Means sharing a common letter (s) in each columı not significantly different $p > 0.05$ by Tukey's multiple comparison test.

In a study to increase the yield of cauliflower, Hafifah *et al.* (2016) had observed an enhancement of soil physical and chemical properties, by the application of *T. diversifolia* as a green manure along with cow manure. Green manure of *T. diversifolia* contributed an increase in soil organic carbon, total N, total porosity, P availability and K exchange and a decrease in soil density either singly or in combination with other treatments. These findings are also applicable for introduction of *T. diversifolia* as a green manure in organic farming. Dense growth of *T. diversifolia* and *M. scandens* probably makes them ideal sources of green manures along with a wide availability in Sri Lanka.

Decomposition rates

The mass loss patterns of the selected invasive plants are presented in figure 1, where the mass remaining is expressed as a percentage of the initial mass of the leaves. After 112 days, the remaining mass was constant for all the invasive plants (Fig. 1). During the study period, *M. scandens* and *T. diversifolia* showed a rapid decrease in mass in the initial phase than that in the others. As decomposition proceeds, the decomposers use the soluble components and relatively easily degradable components like sugars, starches, and proteins. Therefore, during the initial phases, the decomposition rate is higher than in the later phases, the more recalcitrant materials like lignin, tannins, celluloses, and hemicelluloses being decomposed at much slower rates (Loranger *et al*. 2002).

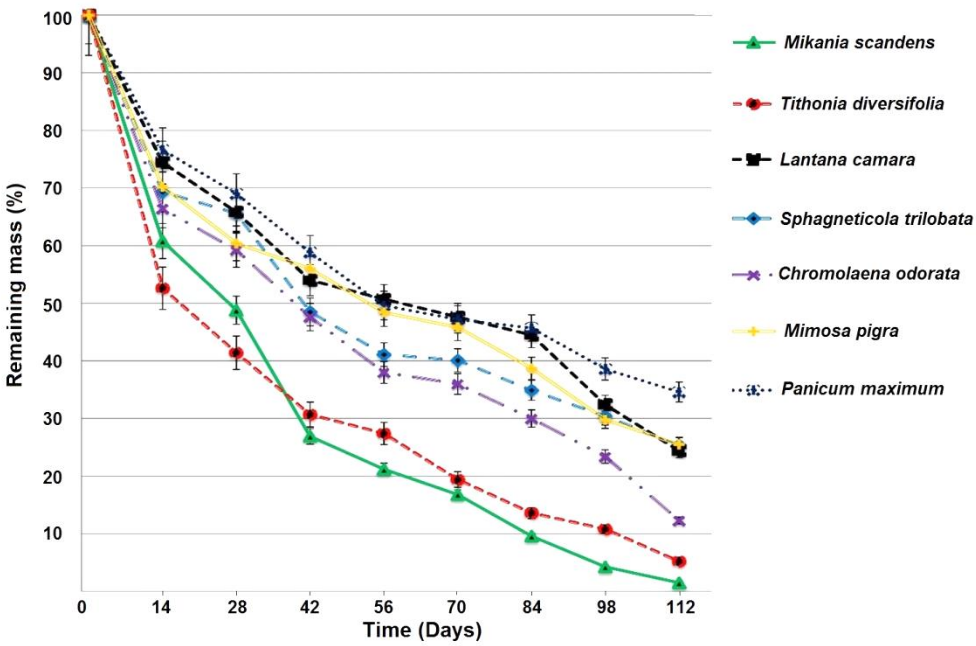

Figure 1. Mean remaining mass (%) of invasive plants during decomposition period. [Error bars represent the mean of five replicates ± standard error]

A higher decomposition factor (k value) indicates a higher decomposition rate (Hartemink & Sullivan 2001). *M. scandens* (k= 12.91 per year) and *T. diversifolia* (k= 10.77 per year) exhibited significantly higher ($p<0.05$) decomposition rates compared to that of other specie *P. maximum* showed the lowest decomposition rate (k= 3.41 per year) than that of the other plant species (Table 4). Several studies have adopted the litterbag technique to determine the effect of litter quality on decomposition rates (Swarnalatha & Reddy 2011, Guendehou *et al.* 2014).

Table 4. Leaf litter decomposition rates (k values) of the selected invasive plants calculated using first odder exponential decay modal ($Y = e^{-k \times t}$) and correlation coefficient (R^2).

Plant species	k- value	R^2
Mikania scandens	12.91^{a}	0.965
Tithonia diversifolia	10.77^{a}	0.947
Lantana camara	4.83^{bc}	0.936
Sphagneticola trilobata	5.11^{bc}	0.974
Chromolaena odorata	8.00^{ac}	0.881
Mimosa pigra	4.14^{bc}	0.968
Panicum maximum	3.41^{b}	0.940

Note: Means sharing a common letter (s) in each column are not significantly different $p > 0.05$ by Tukey's multiple comparison test.

Leaf litter of different plant species has diverse nutrient release patterns, which are related to leaf quality of initial nitrogen contents and C: N ratio (Swarnalatha & Reddy 2011). Higher decomposition rates were observed with low C:N ratio and high nitrogen content, in comparison to high C:N ratio with low nitrogen content. This suggests that the C:N ratio and initial N content could be the main factors for efficient litter decomposition. Previous studies have revealed that the total nitrogen content accelerates litter decomposition (Swarnalatha & Reddy 2011). *M. scandens* and *T. diversifolia* also showed higher nitrogen contents (3.44% and 3.28% respectively) and low C:N ratio (4.8 and 6.1 respectively) which accelerate the decomposition rates in this study. Even though, the decomposition rate of *P. maximum* was significantly lower compared to that of other species, due to the higher fiber content (20.4%) low nitrogen content (1.27%) with high C:N (26.5) ratio values. *M. scandens* and *T. diversifolia* contained higher nutrient contents and displayed higher decomposition rates. Rapid nutrient release from added organic materials is beneficial, especially for short duration crops.

CONCLUSION

Based on the nutrient content and decomposition rates of the selected invasive plants, *Mikania scandens* and *Tithonia diversifolia* could be suggested as plant base substrates for the formulation of compost. *Panicum maximum* has low nutrients, but significantly a higher content of crude fiber, can also be suggested to incorporate with other selected species in preparation of compost, for improving the soil physical properties. Combination of *M. scandens*, *T. diversifolia* and *P. maximum* can be recommended for a cost effective nutrient rich compost preparation and also as one of the solution for removal of invasive plants from ecosystems in another aspect.

ACKNOWLEDGMENTS

The Horticultural Research and Development Institute (HORDI) in Gannoruwa and CIC Soil, Plant and Water Analytical Laboratory in Dambulla are acknowledged for providing necessary research facilities. Financial support from the Ministry of Higher Education is also highly appreciated.

REFERENCES

Agbede TM, Adekiya AO & Ogeh JS (2013) Effects of *Chromolaena* and *Tithonia* mulches on soil properties, leaf nutrient composition, growth and yam yield. *West African Journal of Applied Ecology* 21(1): 15–29.

Akanbi WB, Adebayo TA, Togun OA, Adeyeye AS & Olaniran OA (2007) The use of compost extract as foliar spray nutrient source and botanical insecticide in *Telfairia occidentalis. World Journal of Agricultural Sciences* 3(5): 642–652.

Akanbi WB, Akande MO & Adediran JA (2005) Suitability of composted maize straw and mineral nitrogen fertilizer for tomato production. *Journal of Vegetable Science* 11(1): 57–65.

Alexander M (1977) *Introduction to soil microbiology, 2nd edition*. John Wiley and Sons, New York, pp. 68–70.

AOAC (1990) *Appendix A, Analytical Techniques*, Determination of Crude Fiber content. Available from: http://studentsrepo.um.edu.my/2346/12/LAMPIRAN.pdf (accessed: 02 Mar. 2018).

Bernhart DN & Wreath AR (1955) Colorimetric determination of phosphorus by modified phosphomolybdate method. *Analytical Chemistry* 27(3): 440–441.

Guendehou GHS, Liski J, Tuomi M, Moudachirou M, Sinsin B & Makipaa R (2014) Decomposition and changes in chemical composition of leaf litter of five dominant tree species in a West African tropical forest. *Tropical Ecology* 55(2): 207–220.

Hafifah H, Sudiarso S, Maghfoer MD & Prasetya B (2016) The potential of *Tithonia diversifolia* green manure for improving soil quality for cauliflower (*Brassica oleracea* var brotrytis L.). *Journal of degraded and mining lands management* 3(2): 499–506.

Hartemink AE & Sullivan JNO (2001) Leaf litter decomposition of *Piper aduncum, Gliricidia sepium* and *Imperata cylindrica* in the humid lowlands of Papua New Guinea. *Plant and Soil* 230: 115–124.

Hsieh CF, Fang HC, Nan K & Hsu KN (1996) Effect of continuous use of organic manures on the growth and yield of vegetable soybean and cabbage. *Organic Agriculture* 46: 1–10.

Jackson ML(1973) *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi, pp. 42–48.

Jama B, Palm CA, Buresh RJ, Niang A, Gachengo C, Nziguheba G & Amadalo B (2000) *Tithonia diversifolia* as a green manure for soil fertility improvement in western Kenya. *Agroforestry Systems* 49(2): 201–221.

Johansson MB (1995) The chemical composition of needle and leaf litter from Scots pine, Norway spruce and white birch in Scandinavian forests. *Forestry* 68: 49–62.

Kjeldahl J (1883) A New Method for the Determination of Nitrogen in Organic Substances. *Zeitschrift für Analytische Chemie* 22: 366–382.

Loranger G, Ponge JF, Imbert D & Lavelle P (2002) Leaf decomposition in two semi-evergreen tropical forests: influence of litter quality. *Biology Fertile Soils* 35: 247–252.

Nziguheba G, Merckx R, Palm CA & Mutuo P (2005) Combined use of *Tithonia diversifolia* and inorganic fertilizers for improving maize production in a phosphorus deficient soil in Western Kenya. *Agroforestry Systems* 55(3): 165–174.

Olabode OS, Ogunyemi SWB, Akanbi GO & Babajide PA (2007) Evaluation of *Tithonia diversifolia* (Hemsl.) A gray for soil improvement. *World Journal of Agricultural Sciences* 3(4): 503–507.

Reddy MV & Venkataiah B (1989) Influence of microarthropod abundance and climatic factors on weight loss and mineral nutrient content of Eucalyptus leaf litter during decomposition. *Biology and Fertility of Soils* 8: 319–324.

Sangakkara UR, Liedgens M & Soldati A (2004) Root and shoot growth of maize (*Zea mays*) as affected by incorporation of *Crotalaria juncea* and *Tithonia diversifolia* as green manures. *Journal of Agronomy and Crop Science* 190: 339–346.

Sariyildiz T & Anderson JM (2003) Interactions between litter quality, decomposition and soil fertility: a laboratory study. *Soil Biology and Biochemistry* 35: 391–399.

Shokalu AO, Ojo AO, Adewoin DT E & Azeez JA (2010) Comparing the use of *Tithonia diversifolia* and compost as soil amendments for growth and yield of *Celosia argentea. New York Science Journal* 3(6): 13–3.

Swarnalatha B & Reddy M (2011) Leaf litter breakdown and nutrient release in three tree plantations compared with a natural degraded forest on the coromandel coast (puducherry, india). *Eco-tropical* 17: 39–51.

Swift MJ, Heal OW & Anderson JM (1979) Decomposition in terrestrial ecosystems. 3rd edition. Blackwell Scientific publications, Oxford, pp.75–78.

Veeragurunthan V (2009) Effect of commercial fertilizer (Urea) and S.L.F. of *Entermorpha intestinalis* on the growth of *Capsicum annum* L. *Seaweed Research and Utilization* 31(1): 158–163.

Walkley A & Black IA (1934) An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* 37: 29–37.

Weerakoon D (2008) *Management of invasive plants in protected areas by the Department of Wildlife Conservation: Lessons learned and the way forward*. National symposium on invasive Alien species, Sri Lanka, pp. 57–62.