Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.3, No.8, 2013

Influence of Seasonality and *Eucalyptus* Plantation Types on the Abundance and Diversity of Litter Insects at the Arboretum of Ruhande in Southern Rwanda

Donat Nsabimana
National University of Rwanda, Department of Biology, Faculty of Science, B.P. 117 Butare, Rwanda.
E-mail of the corresponding author: dnsabimana@nur.ac.rw

Abstract
The aim of this study was to document on the influence of seasonal variability and *Eucalyptus* plantation types on the abundance and diversity of litter insects using the Arboretum of Ruhande in Rwanda. Insect individuals were sampled and fixed in a 10% formalin solution, and brought to the laboratory for identification to order and family levels. Insect individuals were classified in 9 orders and 27 families. Coleoptera and Hemiptera orders were the most diversified with eight families each. The results indicated that the order Hymenoptera showed the highest abundance in all seasons, followed by Coleoptera, Hemiptera, and Isoptera orders. Results indicated that stands of four *Eucalyptus* species have litter insect diversity which was higher than that of native *Entandrophragma excelsum* which was set as a reference. Insects abundance combined with Shannon diversity indices in different seasons indicated that stands of *Entandrophragma excelsum*, *Eucalyptus grandis*, *Eucalyptus maidenii* and *Eucalyptus saligna* have the best conditions for the establishment of diverse insects in the litter. Therefore, negative ecological effects of *Eucalyptus* species on insect biodiversity may not be exclusively attributed to the whole genera. Seasonal variation of litter insect diversity indicated that dry season (September 2012) had the highest Shannon diversity indices relative to those in rainy seasons (January and April 2013). This indicates that heavy rain negatively impact the survival and diversity of litter insects. High variability of litter insects is attributed to the variability of habitat conditions, including understory vegetation, litter cover, and soil chemistry. Further studies on seasonal variation of litter insects in other Rwandan ecological regions are needed.
Keywords: *Entandrophragma*; *Eucalyptus*; Insects; Hymenoptera; Seasonal variation.

1. Introduction

Insects play important ecological processes on earth, including plant pollination, organic matter decomposition and nutrient cycling, and are indicator of environmental changes (Kevan, 1999; Rocha *et al*., 2010). Insects are food for majority of animals and are source of useful products including honey, oils, natural medicines, dyes, and silk (Mc Gavin, 2002), and are the most numerous life forms on earth (Borror *et al*., 1989). Insects are thought to make good indicators as they respond quickly to environmental stress, have short generation times, and are known to be easily sampled and identified (Peck *et al*., 1998).

Several groups of insects are known to decline in number during the wet mid-season, seldom exhibiting an abundance that is lower than that observed during a dry season (Robinson and Robinson, 1970; Boinski and Fowler, 1989; Pinheiro *et al*., 2002). Variability in temperature, photoperiod, rainfall, humidity, and litter decomposition rates, variation in availability of foods resources have noted to influence seasonal activity of insects in tropical region (Tauber and Tauber, 1976; Delinger, 1986; Wolda 1988; Basset, 1991).

Eucalyptus plantations dominate large areas in Africa and the world as a result of increasing demand for fuel wood and construction materials (Demel, 2000; FAO, 2011). However, *Eucalyptus* was described for negative environmental impact, such as adverse effect of the leaf litter and soil humus, high consumption of soil nutrients, inability to prevent soil erosion, inhibition of growth of other plants in the understory and also failure to provide food supplies or adequate habitat for wildlife (Cannell, 1999; FAO, 2011). However, the results of different studies were not conclusive about the influence of the plantations on the abundance of invertebrates including insects, even though most studies reported a negative influence on invertebrates (Zahn *et al*., 2009). Therefore, the present study aims to provide information on the impact of *Eucalyptus* plantations on litter insects. Currently, no study has been conducted in Rwanda assessing the abundance of litter insects under *Eucalyptus* plantations.

The general objective of this study was to document on the seasonal variation of litter insects in some *Eucalyptus* plantation types at the Arboretum of Ruhande. The specific objectives were: (i) to determine the abundance of insects in each season; and (ii) to compare insect diversity between *Eucalyptus* plantations and another plantation type that is native to Rwanda, *Entandrophragma excelsum*. It was hypothesized that (i) insect orders are distributed unequally in different stands of *Eucalyptus* species; (ii) *Eucalyptus* plantation may have negative impact on insect abundance and diversity in comparison to the native *Entandrophragma excelsum*; and (iii) Hymenoptera may be the most abundant order among insects.

2. Materials and Methods

2.1. *Study area*

The Arboretum of Ruhande is located in southern Rwanda (Longitude: 29°44´ E, Latitude: 2° 36´ S) and comprise an altitude range between 1,638 and 1,737m and an area of about 200 ha (Nsabimana *et al*., 2009). It is subdivided into about 504 plots. Established in 1933, the Arboretum of Ruhande was conceived as a research center that may produce ecologically adapted silvicultural species and providing tree seeds at national level. It is composed of over 207 native and exotic species, including 143 hardwoods with 69 *Eucalyptus* species, 57 softwoods and 3 bamboo species. Each species is planted in a plot of 50×50m and each plot is numbered (Nsabimana *et al*., 2008). The Arboretum of Ruhande is also the habitat of diversity of animal species including monkeys, gazelles, birds, small mammals, and bats (Stanga, 1991), but their diversity is not well documented.

2.2. *Insect sampling and identification*

This research was conducted on 24 plots covering eight plantation species, including seven *Eucalyptus* plantation types: *Eucalyptus citriodora* (plots 58, 211, 456), *Eucalyptus grandis* (plots 218, 220, 265), *Eucalyptus maculata* (plots 6, 446, 458), *Eucalyptus maidenii* (179, 377, 452), *Eucalyptus microcorys* (plots 77, 367, 448), *Eucalyptus saligna* (plots 20, 375, 442), and *Eucalyptus tereticornis* (plots 109, 110, 540) and a stand which is native to Rwanda, *Entandrophragma excelsum* (plots 44, 54, 78). Three subplots of 1m^2 were selected randomly in each plot leaving 5m at the edge.

Litter insects were collected in three different seasons. Firstly, in the end of long dry season (September, 2012), second in January 2013 at the end of short rainy season that extends from October to December and thirdly, in April 2013 during the main rainy season. Insects were hand searched and collected using the square pick–up point technique (McGavin, 2007; Bharti *et al*., 2009).

Each site was sampled by using a 1m^2 wooden quadrat frame on the forest floor and then scraping up litter and loose humus. Three sampling locations placed randomly in each plot were sampled and each separated from other by at least 5m. Insects were collected and put into jars containing killing agent, 10% formalin solution (Borror, 1970; White, 2000). Samples were collected as quickly as possible to prevent insects from escaping (Anu *et al*., 2009). Because Hymenoptera are generally in colony and too many to count, the estimation of entire population was used (Seber, 1982). Collected insects were transported in the laboratory and were classified using identification keys in the literature (Borror, 1970; Picker *et al*., 2004).

2.3. *Data analysis*

Microsoft Excel sheet was used for entering data which was thereafter analyzed using Biodiversity Professional software (McAleece *et al*., 1997) which has calculated the diversity indices such as Shannon and Evenness indices (Weaver and Shannon, 1949). A *Eucalyptus* species with a large H´ value is considered to be highly diversified while the one having little diversity has a low H´ value. Computed relative frequency was used to compare insect families.

3. Results

3.1 Seasonal variation of litter insects

In September 2012, 1818 insect individuals were sampled and classified in 8 orders, and one unknown group. The order Hymenoptera dominated with 55% of all insects sampled, followed by Hemiptera, Isoptera and Coleoptera orders (Table 1). Insects were more abundant in the litter of *Entandrophragma excelsum* stand (28.99%) followed by *Eucalyptus tereticornis* and *E. grandis* stands (Table 1). Diversity indices were highest for litter insects sampled under *E. maideii*, *E. grandis*, and *Entandrophragma excelsum* stands (Table 4).

In January 2013, 2671 insect individuals were sampled and classified in 10 orders and an unknown group. The majority of sampled insects were Hymenoptera (85.5%) (Table 2). The highest figures of insects were collected from the litter of *Eucalyptus saligna* stand (21.8%), followed by *E. maidenii* stand (18.6%) (Table 2). Diversity indices were highest for litter insects sampled under *E. maculata* and *Entandrophragma excelsum* stands, but during this period, Shannon diversity indices declined in comparison to those in September 2012 (Table 5).

In April 2013, 3068 insect individuals were sampled, and were classified in nine orders (Table 3). The order Hymenoptera was the most dominant with 91.3% of total insect individuals sampled. Insect individuals were the most abundant in the litter of *Eucalyptus tereticornis* stand (29.3%), followed by *E. saligna* stand (21.87%), and *E. grandis* stand (13.1%) and they were least abundant in the litter of *Entandrophragma excelsum* and *Eucalyptus microcorys* stands (Table 3). The order Hymenoptera was the most abundant with 91.3% of total insect individuals. Diptera were only observed during this period and at very low abundance (Table 3). During this period, Shannon diversity indices further declined in comparison to those in January 2013, especially for insects sampled under all *Eucalyptus* plantations, but insect diversity index increased under *Entandrophragama excelsum* stand (0.562) (Table 5).

Classification of insect individuals sampled in all three seasons resulted in 9 orders and 27 families in total (Table 4). Coleoptera and Hemiptera orders were the most diversified with eight families each, followed by

Orthoptera order which had four families (Table 4). The most dominant insect families were Formicidae (83%), followed by Reduviidae (3.22%), Termitidae (2.82%), Gryllidae (1.14%), Blaberidae (0.94%) and Scarabaeidae (0.78%) (Table 4). In general, it can be suggested that Shannon diversity indices were lowest for litter insects sampled during rainy periods (January and April 2013; Table 5) and highest for insects sampled at the end of drought period (September 2012; Table 5).

Table 1. Abundance of litter insects as sampled in September 2012 under eight plantation types at the Arboretum of Ruhande.

Plantation species	Blattodea	Coleoptera	Hemiptera	Hymenoptera	Isoptera	Lepidoptera	Mantodea	Orthoptera	Unknown	%
E. excelsum	68	44	51	258	90	0	0	16	0	28.99
E.citriodora	2	7	22	96	0	1	0	3	0	7.21
E. grandis	12	24	35	129	68	6	1	13	2	15.95
E. maculata	1	6	9	82	0	0	0	6	0	5.72
E. maidenii	7	16	27	105	25	11	1	14	0	11.33
E. microcorys	1	5	48	43	0	2	0	2	0	5.56
E. saligna	3	13	33	84	15	2	1	5	0	8.58
E. tereticornis	31	22	31	196	0	15	0	8	0	16.67
Total	125	137	256	993	198	37	3	67	2	
Frequency (%)	6.9	7.5	14	55	11	2	0.2	3.7	0.1	

Table 2. Abundance of litter insects as sampled in January 2013 under eight plantation types at the Arboretum of Ruhande.

Plantation species	Blattodea	Coleoptera	Diptera	Hemiptera	Hymenoptera	Isoptera	Lepidoptera	Mantodea	Orthoptera	Plecoptera	Diplura	Unknown	%
E. excelsum	9	7		5	195	2	5		8			3	8.5
E. citriodora	1	6		10	190	0	0		3	0	1	0	7.9
E. grandis	3	34		2	325	10	2	1	5			1	14.3
E. maculata	0	15		7	75	0	2	1	3	1		4	4.0
E. maidenii	2	12		17	455	0	8	1	3			0	18.6
E. microcorys	0	2		12	325	3	0		5			0	13.0
E. saligna	2	20		4	490	57	3		4			1	21.8
E. tereticornis	5	26		14	230	17	9	1	3	1		3	11.6
Total	22	122		71	2285	89	29	4	34	2	1	12	
Frequency (%)	0.8	4.6	0	2.7	85.5	3.3	1.1	0.1	1.3	0.1	0.04	0.4	

Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.3, No.8, 2013

Table 3. Abundance of litter insects as sampled in April 2013 under eight plantation types at the Arboretum of Ruhande.

Plantation species	Blattodea	Coleoptera	Diptera	Hemiptera	Hymenoptera	Isoptera	Lepidoptera	Mantodea	Orthoptera	Unknown	%
E. excelsum	8	7		4	52		3	1	6	1	2.67
E. citriodora	7	7		16	165	1	2		3	1	6.58
E. grandis	7	10		4	370		1	3	8		13.2
E. maculata	1	10		3	240				8		8.54
E. maidenii	17	6		8	310		3		7		11.4
E. microcorys	1	7	1	11	175		1		2		6.45
E. saligna	13	11		17	620			1	9		21.87
E. tereticornis	9	9	1	5	870		2	1		2	29.3
Total	63	67	2	68	2802	1	12	6	43	4	
Frequency (%)	2.05	2.18	0.07	2.21	91.3	0.03	0.39	0.19	1.40	0.13	

Table 4. Orders, families and relative frequency (%) of litter insects sampled in eight plantation types at the Arboretum of Ruhande, during three seasons of the study.

Order	Family	Relative frequency (%)
Blattodea	Blaberidae	0.94
	Blattellidae	0.38
	Blattidae	0.56
Coleoptera	Buprestidae	0.01
	Carabidae	0.57
	Chrysomelidae	0.84
	Coccinellidae	0.04
	Curculionidae	0.06
	Scarabaeidae	0.78
	Staphylinidae	0.58
	Tenebrionidae	0.21
	Larva	0.93
Diplura	Japygidae	0.04
Hemiptera	Alydidae	0.03
	Cydnidae	0.38
	Lygaeidae	0.06
	Miridae	0.09
	Notonectidae	0.06
	Pentatomidae	0.41
	Reduviidae	3.22
	Scutelleridae	0.56
Hymenoptera	Formicidae	83.03
Isopoda	Termitidae	2.82
Lepidoptera	Larva	1.13
Mantodea	Mantidae	0.19
Orthoptera	Acrididae	0.41
	Euschmidtidae	0.01
	Gryllidae	1.14
	Tettigoniidae	0.24
Unknown	Larva	0.06
	Unknown	0.21

Table 5. Shannon diversity indices for litter insects sampled in September 2012, January 2013 and April 2013.

Plantation species	September 2012		January 2013		April 2013	
	Shannon index	Evenness	Shannon index	Evenness	Shannon index	Evenness
Entandrophragma excelusum	0.632	0.355	0.329	0.158	0.562	0.270
Eucalyptus citriodora	0.378	0.211	0.196	0.109	0.33	0.158
Eucalyptus grandis	0.667	0.303	0.274	0.125	0.18	0.092
Eucalyptus maculata	0.336	0.208	0.472	0.227	0.167	0.104
Eucalyptus maidenii	0.671	0.322	0.182	0.093	0.231	0.129
Eucalyptus microcorys	0.463	0.258	0.134	0.083	0.223	0.114
Eucalyptus saligna	0.594	0.285	0.266	0.128	0.164	0.091
Eucalyptus tereticornis	0.514	0.287	0.445	0.193	0.085	0.041

3. Discussion

Litter insects under plantations of *Eucalyptus* species and *Entandrophragama excelsum* stands were highly variable (Tables 1 to 3). This may be explained by nutrients availability and soil conditions that were variable. Field observation showed that these plantations have undercover vegetation showing a diversity of plants, and it is argued that high vegetation diversity supports in turn a high invertebrate diversity (Teodorescu and Cogãlniceanu, 2002). Thus, most insects were abundant such as Hymenoptera, Hemiptera, Coleoptera and Orthoptera (Tables 1–3) which may feed on various vegetation present under these plantations. These results are similar to those obtained in Australia showing that phytophagous groups such as Coleoptera, Lepidoptera, and Hemiptera were highly abundant (Margaret, 2006). Coleoptera and Hemiptera families were the most diversified, having 8 families each (Table 4), suggesting that they have high potential to utilize different nutrient resources available under forest plantations investigated. This supports the idea that Coleoptera are considered environmental indicators in forest area (Rocha *et al*., 2010).

The results show that the order Hymenoptera dominated in all seasons, being 55% in September 2012, 85.5% in January 2013, and 91.3% in April 2013 (Tables 1–3). This may result to the fact that this order is the most dominant among ground insects that forage on decaying debris and having the capacity for inhabiting fallen leaves and litter. A dominance of Hymenoptera (ants) has also been documented in western Ghasts, India (Sabu *et al*., 2008), in Australia and Africa (Frith and Frith, 1990; Burgess *et al*., 1999) and Rocha *et al*. (2010) suggested them to be used as environmental indicators in many ecosystems. This pattern may be probably related to their ability to exploit nutrients resources which are associated with fallen foliage (Backus, 1985; Cherret, 1989; Forgarait, 1998). The abundance of Hymenoptera in September 2012 was low compared to that in other seasons (Table 1). This may be caused by the reduction of nutrients in litter due to dry conditions that reduce or limit their foraging ability (Bruhl *et al*., 1999).

Stands of *Eucalyptus maidenii*, *Eucalyptus grandis, and Entandrophragma excelsum* showed the highest Shannon diversity indices for litter insects sampled in September 2012 (Table 5). This may indicate that these plantation species favor the establishment of arthropods abundance and diversity (Murdoch *et al*., 1972). The stands of *Eucalyptus maculata* and *Eucalyptus tereticornis* have a high Shannon diversity index for insect sampled in January 2013 (Table 5), this can be explained by the fact that these *Eucalyptus* species have been successful in rainfall conditions with a moderate to fairly severe dry season. *Eucalyptus tereticornis* performs at variety of soil types, well drained soil of fairly light texture, including alluvial soils, silts, and clays and a neutral or slightly acidic pH is suitable (Orwa *et al*., 2009), and so different soil type may give nutrients that favor the existence of many different insects. *Eucalyptus maculata* grows in dry highlyland areas and provides good shade (Oballa *et al*., 2010), and large amount of litter, which provide important nutrients that may support a diversity of insects.

Stands of *Eucalyptus citriodora, Eucalyptus maidenii and Eucalyptus microcorys* have the highest Shannon diversity indices for litter insects sampled in April 2013 (Table 5). *Eucalyptus citriodora* has adapted to cultivation in a number of countries with widely different climate and soil types. Research has showed that *Eucalyptus maculata* has similar characteristics as *Eucalyptus citriodora* (Oballa et *al*., 2010), and these *Eucalyptus* species may have factors favoring insects.

The stand of *Entandrophragma excelsum* has shown high diversity of insect in all seasons (Table 5), this plantation may have conditions favoring insects, and it was indicated that insects are generally abundant where favorable environment conditions (light, litter fall, and food) are found (Adeduntan, 2009).

In general, results indicated that four *Eucalyptus* species types have litter insect diversity which is higher or

comparable to that of native *Entandrophragma excelsum* which was set as a reference. These stands are *E. tereticornis*, *E. saligna*, *E. maidenii* and *E. grandis* (Tables 1–3). The results of litter insects abundance (Tables 1–3) combined with Shannon diversity indices (Table 5) in different seasons indicate that *Entandrophragma excelsum*, *Eucalyptus grandis*, *Eucalyptus maidenii* and *Eucalyptus saligna* have the best conditions for the establishment of diverse insects in the litter. On the other hand, remaining *Eucalyptus* stands have lower conditions for the litter insect diversity (Table 5). Therefore, negative ecological effects of *Eucalyptus* species on biodiversity that was noted by a number of authors (Cannell, 1999) may not be attributed to the whole genera.
Seasonal variation of litter insect diversity indicated that dry season (September 2012) had the highest Shannon diversity indices relative to those in rainy seasons (January 2013 and April 2013; Table 5). This may indicate that heavy rain negatively impacts the survival and diversity of insects, as their body is vulnerable to rain conditions.

5. Conclusions

Insect individuals collected in the litter of eight plantation types were classified in 9 orders and 27 families. Coleoptera and Hemiptera orders were the most diversified with eight families each. The results indicated that the order Hymenoptera dominate in all season, suggesting its high potential to use food resources available in forest ecosystems, utilizing a wide range of plant species. Results indicated that some stands of *Eucalyptus* species had similar/comparable litter insect diversity with native *Entandrophragma excelsum* stand; those include *E. tereticornis*, *E. grandis*, *E. maidenii*, and *E. saligna*. On the other hand, some other *Eucalyptus* stands present negative impacts on the diversity of litter insects, which may be coupled to growth inhibition of understory vegetation which may be the habitat and food for the litter insects. Therefore, it is concluded that the negative ecological impacts of *Eucalyptus* species on biodiversity may be species specific and thus should be discussed case by case. It is suggested to continue seasonal variation of insect diversity in other Rwandan regions for a final generalization of the present finding.

Acknowledgements

I express special gratitude to the Rwanda Agriculture Board (RAB) that authorized to conduct this research using the Arboretum of Ruhande. I also thank BSc students that have assisted in field data collection, including J.D. Dusabimana, C.S. Iradukunda and F. Sebera.

References

Adeduntan S.A., (2009). Influences of human activities on diversity and abundance of insects in Akure Forest Reserve, Ondo State, Nigeria. International Journal of Biological and Chemical Sciences 3(9), 1320–1335.
Anu A., Sabu T.K., Vineesh P.J., (2009). Seasonality of litter insects and relationship with rainfall in wet evergreen forest in south Western Ghats. Journal of Insects Science 9, 46. Available online: insectscience.org/9.46.
Backus E.A., (1985). Anatomical and sensory mechanisms of plant hopper and leafhopper feeding behavior. New York, Wiley. pp.163–188.
Basset Y., (1991). The seasonality of arboreal arthropods foraging within an Australian rainforest tree. Ecological Entomology 16, 265–278.
Bharti H., Paul S.Y., Kaur A., (2009). Seasonal patterns of ants (hymenoptera: formicidae) in Punjab shivalik. Department of zoology, Punjabi University, Patiala (pb.) India-147002, Halters, 1(1), 36–38.
Boinski S., Fowler N.L. (1989). Seasonal patterns in a tropical lowland forest. Biotropica 21, 223–233.
Borror D.J., Triplehorn H.A., and Johnson N.F., (1989). An introduction to the study of insects, 6th Edition, Saunders College publishing, Philadelphia. pp 875.
Borror D., White K., Richard E., (1970). Field guide to insects, Houghton Mifflin Company. pp 1–6.
Bruhl C.A., Mohamed M., Linsenmoir K.E., (1999). Altitudinal of the leaf ants along a transect in primary forest on mount Kinabalu, Sabah, Malaysia. Journal of Tropical Ecology 16, 265–267.
Burgess N.D., Ponder, K.L., Goddard J. (1999). Surface and leaf litter arthropods in the coastal forest of Tanzania. African Journal of Ecology 37(3), 355–365.
Cannell, M.G.L. (1999). Environmental impacts of forest monocultures: water use, acidification, wildlife conservation, and carbon storage. New Forests 17, 239–262.
Cherret, J.M. (1989). Leaf-cutting ants. Biogeographical and ecological studies. Ecosystem of the World Tropical Rain Forest ecosystem. pp. 473–488.
Demel, T. (2000). Facts and experience on *Eucalyptus* in Ethiopia and elsewhere: ground for making wise and informed decision. Workshop on *Eucalyptus* Dilemma, 15 November 2000.
FAO, (2011). *Eucalyptus* in East Africa Socio-economic and environmental issues. Planted Forests and Trees Working Papers FP46/EFAO, Rome, Italy.

Frith D., Frith C., (1990). Seasonality of litter invertebrate populations in Australia upland Tropical Rain Forest. Biotropica, 22(2), 181–190.
Forgarait, P.J. (1998). Ants biodiversity and its relationship to ecosystem functioning: a review. Biodivers. Conserv. 7, 1221–1244.
Kevan, P.G., (1999). Pollinators as bioindicators of the state of environment: species activity and diversity. Agr. Ecosyst. Environ., 74, 373–393.
Margaret, D.L. (2006). Seasonal variation in insect abundance among three Australian rain forest, with particular reference to phytophagaous types. School of Biological Sciences, Sydney University. pp. 357.
McAleece N., Gage J.D., Lambshead J., Patterson G.L.J., (1997). Biodiversity Professional. The Natural History Museum & The Scottish Association for Marine Science, London.
McGavin, C.G. (2007). Expedition Field Techniques insects and other terrestrial arthropods. Blandford Press., pp 27–98.
McGavin, G.C. (2002). Insects, spiders and other terrestrial arthropods.Dorling Kindersley Limited, USA, 255 pp.
Murdoch W.W., Evans F.C., and Peterson C.H., (1972). Diversity and pattern in plants and insects. Ecology 53, 819–829.
Nsabimana, D., Klemedtson, L., Kaplin, B.A., Wallin, G., (2008). Soil carbon and nutrient Accumulation under forest plantations in southern Rwanda. African Journal of Environmental Science and Technology 2(6), 142–149.
Nsabimana D., Klemedtsson L., Kaplin B.A., Wallin G., (2009). Soil CO_2 flux in six monospecific forest plantations in southern Rwanda. Soil Biology and Biochemistry 41, 396–402.
Oballa P.O., Konuche P.K.A., Muchiri M.N., Kigomo B.M. (2010). Facts on growing and use of *Eucalyptus* in Kenya. pp. 3–17.
Orwa C., Mutua A., Kindt R., Jamnadass R., Simons A., (2009). Agroforestry Database and selection guide version 4.0 (http: www.worldagroforesty.org/af/treedb/).
Peck S.L., McQuaid B., Campbell C.L., (1998). Using ants species (hymenoptera: formicidae) as biological indicator of agro ecosystems condition. Environ. Entomol. 27, 1102–1110.
Picker M., Griffths C., and Weavings, A. (2004). Field Guide to insects of South Africa. Struik Publisher, pp. 250.
Pinheiro M.H.O., Monteiro R., Cesar O., (2002). Levantamento fitossociológicoda floresta estacional semidecidual do Jardim Botânico. Municipal de Bauru, São Paulo. Naturalia 27, 145–164.
Robinson M.H., Robinson B., (1970). Prey caught by a sample population of the spider *Argiope argentata* (Araneae: Araneidae) in Panama: A year's census data. Zoological Journal of Linnean Society 49, 345–358.
Rocha J.R.M., Almeida J.R., Lins G.A., Durval A., (2010). Insects as indicators of environmental changing and pollution: A review of appropriate species and their monitoring. Holos Environ. 10, 250–262.
Seber G.A.F. (1982). The estimation of animal abundance. 2nd ed., Griffin, London, 654 pp.
Stanga., S. (1991). Plan d'amenagement et de gestion de l'arboretum de Ruhande, 1991-2000. Institut des Sciences Agronomiques au Rwanda.
Tauber M.J., Tauber C.A., (1976). Insect seasonality: Diapause maintenance, termination and post diapause development. Annual Review of Entomology 21, 81–107.
Teodorescu I., Cogãlniceanu D., (2002). Arthropods diversity in the Letea and Caraorman forests, the Danube Delta (Romania). University of Bucharest 34, 721–725.
Weaver W., and Shannon C.E., (1949). The mathematical theory of communication, Urbana, Illinois. University of Illinois press, 34 pp.
White, (2000). Terrestrial ecosystem model: Net primary production controls. Earth Interactions, 4(3), 1–84.
Wolda H., (1988). Insect seasonality: Why? Annual Review of Ecology and Systematic 19, 1–18.
Zahn A., Rainho R., Rodrigues L., Palmeirim JM., (2009). Low macro-arthropod abundance in exotic *Eucalyptus* plantations in the Mediterrane.