



Morphology and Biomass Traits of *Gmelina arborea* as Influenced by Simulated Insect Leaf Damage

Titus Fondo Ambebe¹ and Lawrence Monah Ndam²

¹Associate Professor, Department of Forestry and Wildlife Technology, College of Technology, The University of Bamenda, Bamibili, Cameroon

²Lecturer, Department of Agronomic and Applied Molecular Sciences, Faculty of Agriculture and Veterinary Medicine, University of Buea, Buea, Cameroon

Abstract

Predicting the growth responses of plants to insect defoliation is complicated by the recovery potential of individual tree species, varieties, provenances, but also the extent of damage, and site conditions. This study investigated the effect of simulated insect leaf damage on growth of *Gmelina arborea* (gmelina) seedlings raised from seeds that were collected from mother trees in Bamessing village of the Bamenda Highlands, Cameroon. The seedlings were subjected to four treatments (control, 2, 4, 6 holes per leaf). Morphology and biomass were determined three months after the initiation of treatments. Height, stem diameter, shoot mass, and root/shoot ratio were unaffected by the insect damage treatments. In contrast, root and total biomass responded to treatments in a similar manner, declining from the control to the 4 holes and 6 holes regimes which resulted in comparable values for each trait. Furthermore, the differences in root and total mass between the control and 2 holes treatment were not statistically significant. The results suggest that an insect damage of low intensity may not compromise the growth of gmelina seedlings. Where an insect outbreak of density high enough to impose severe damage to leaf tissue is anticipated, measures to control insect populations may be warranted as a safeguard against a significant growth decline.

Keywords: *Gmelina arborea*, seedling, growth, leaf damage, insect outbreak.

Introduction

The forest ecosystem is a composite of environmental variables upon which forest productivity and stability depends (Niinemets, U. 2010; Jacquet, J. S. *et al.*, 2012; Jacquet, J. S. *et al.*, 2014). The effects of abiotic factors like CO₂ elevation, nutrient fertilization, soil moisture content, air/soil temperature, atmospheric ozone concentration, acid rain, and light intensity on physiological processes and growth of forest plants have been extensively investigated. For instance, low soil temperature has been found to reduce shoot water potential, stomatal conductance, carbon dioxide assimilation (Day, T. A. *et al.*, 1991; Dang, Q. L. and Cheng, S., 2004; Ambebe, T. F. *et al.*, 2010) and growth (Grossnickle, S. C., 2000; Onwuka, B. M.,

2016). Similarly, the outcome of a recent free-air CO₂ and O₃ enrichment study with Japanese white birch is that total biomass production is enhanced by elevated CO₂ but reduced by elevated O₃, the trends attributable to photosynthetic dynamics (Kitao, M. *et al.*, 2021). In multifactorial experiments, responses to interactions amongst the environment factors have also been detected as exemplified by the growth promoting effect of soil warming on white birch which is attenuated by low moisture stress (Ambebe, T. F. and Dang, Q. L., 2009).

On the other hand, browsing, arthropod attack, disease, competition, and insect pests constitute key biotic influencers of plant

*Corresponding Author:

Titus Fondo Ambebe;

DOI: <http://dx.doi.org/10.21746/aps.2022.11.4.1>

functioning, growth, and forest productivity (Seidl, R. *et al.*, 2011; Navarro, L. *et al.*, 2018; Lavoie, J. *et al.*, 2019). In particular, the discussion on role of insect foliar damage in modifying forest tree performance continues to gain momentum in ecological circles as climate warming promises to further augment the abundance and expand the distribution of insect herbivores (Huttunen, L., 2013). The prediction of physiological and growth responses to defoliation is complicated by the recovery potential of individual tree species, varieties, provenances, extent of damage, and site conditions (Mutikainen, P. *et al.*, 2000; Varnagirytė-Kabašinskienė, I. *et al.*, 2015; Helbig, C. E. *et al.*, 2021), that will result in a plant showing either a decline or a compensation in growth following the removal of leaf tissue (Rogers, W. E. and Siemann, E., 2002; Zhao, W. *et al.*, 2008; Araminienė, V. and Varnagirytė-Kabašinskienė, I., 2015). Moreover, diverse patterns of compensatory growth have been recorded ranging from under-, to equal-, and to over-compensation (Li, C. *et al.*, 2021). Studies with various abiotic and biotic factors have remarkably enriched the literature on the responses of forest plants to environmental stresses and provided a bedrock for developing strategies for improving plant performance in forest ecosystems.

The Bamenda Highlands lies within the Cameroon highlands ecoregion that is comprised of highland forests and grassland patches scattered along the border area between Cameroon and Nigeria (WWF, 2017). The ecoregion extends from an altitude of above 900 m to reach the highest peak of 3011 m at Mount Oku. Characterized by a vegetation that progresses from submontane through montane forests to a subalpine community, the landscape provides a wide range of benefits amongst which are food, wildlife forage, building material, raw materials for rural artisan industries, and water from a rich endowment of catchments. In fact, the biome contains the largest remaining patches of afro-montane forest in Central Africa. However, most of the forest

that once covered the hills and valleys of the area has been lost to unsustainable activities of a high human population that has been attracted by fertile soils and adequate rainfall. Thus, a change of behavior in the use of forests and reforestation are important protective and restorative strategies.

Gmelina arborea (family Lamiaceae, common name gmelina) is a timber species of the Bamenda Highlands whose wood is valued for its lightweight, stability, and durability. The tree attains a height of 30(-40) m with cylindrical bole up to 80(-140) cm in diameter (Adam, K. A. and Krampah, E. 2005). Some medicinal attributes are also linked to the bark of the tree (Ashalatha, M. and Sankh, K. 2014). The rapid growth of gmelina makes it suitable for reforestation programs. Leaf cutting ants and other insects have, however, been detected to cause damage in nurseries and plantations (PROTA, 2016). Like in other plant species, the susceptibility of gmelina to insect attack will likely be exacerbated by climate warming (Jamieson. *et al.*, 2012). Furthermore, the species could face attack from other insect groups which do not currently constitute a threat. This study investigated the effect of simulated insect damage on growth of gmelina seedlings grown from seeds collected from mother plants in a village within the Bamenda Highlands region.

Materials and Methods

Study area

The experiment was conducted in the Reforestation Task Force (RETAFO) nursery situated at Mile 6 Nkwen, Bamenda III Sub-Division, northwest Cameroon. Being one of the three municipalities that make up the metropolitan city of Bamenda, Bamenda III Sub-Division is located between latitude 5° 56' 0'' and 6° 0' 0'' North of the Equator and longitude 10° 10' 0'' and 10° 14' 0'' East of the Greenwich Meridian at an elevation of 1253 m asl. It is bounded to the West by Tubah, to the North by Bamenda I, to the East by Bamenda II and to the South by Bafut Sub-Divisions. Nkwen is the larger of the two autonomous villages that make up Bamenda III Sub-

Division, the other being Ndzah. Bamenda is characterized by a mean annual temperature of 19.3 °C and rainfall of 2567 mm with a rainy season that extends from March to October (Climate-Data.org). The driest month is January with 9 mm rainfall while the wettest is September with 380 mm. February and August are the hottest and coldest months with temperatures of 21.6° C and 17.6° C, respectively.

Experimental design

The plant material was comprised of three-month old seedlings of *gmelina* raised at the RETAFO nursery from seeds that were collected from mother plants at Bamessing (5° 58' 20" North, 10° 21' 47" East; 1191 m asl), Ndop Sub-Division, northwest Cameroon. Only similar-sized seedlings were transplanted from the germination bed to an experimental plot where they were maintained at an inter-plant and row distance of 30 cm. The seedlings were watered immediately following transplant. Subsequently, irrigation was mainly by natural precipitation. The rainwater was, however, supplemented with artificial irrigation using a watering can when the need arose.

Treatments were comprised of 2, 4, 6 holes per leaf of seedling created with a perforator and an unperforated control. They were laid out in a randomized complete block design with two replicates. There were 80

experimental units in the trial distributed equally across treatments and replications. The experiment ran from June to August 2019.

Data collection

At the end of the experiment, three seedlings were randomly selected from each treatment and replication for measurements. The plant height was determined as the linear distance from the root-shoot junction to the tip of the stem while stem diameter was taken with a vernier caliper at the point that divides the height into two equal lengths. The root system was then washed free of soil after severing the plant at the root-shoot junction. The root and shoot components were oven-dried to constant mass and weight.

Statistical analysis

The data were examined for normality and homoscedasticity before being subjected to ANOVA untransformed. When the ANOVA detected a significant treatment effect on a given parameter, Scheffé's test was used for means comparison. All the analyses were performed in Datadesk 6.01 (Data Description, 1996) at $\alpha = 0.05$.

Results and Discussion

Height and stem diameter were not significantly influenced by simulated insect damage (Table 1, Figure 1). In addition, there was no significant main or interactive effect of replication on any of the morphological variables (Table 1).

Table 1: ANOVA p-values for the effect of simulated insect damage on morphology and biomass

Variable	Insect damage	Replication	Insect damage x Replication
Height	0.7100	0.6344	0.3402
Stem diameter	0.8469	0.3155	0.4161
Shoot mass	0.0664	0.3796	0.6554
Root mass	0.0131	0.1289	0.9145
Total mass	0.0302	0.1896	0.7636
Root/Shoot	0.6451	0.7902	0.8218

The tolerance of height and stem diameter to increasing intensities of simulated insect damage is consistent with the findings of other investigators on silver birch (*Betula pendula*) (Varnagirytė-Kabašinskienė, I. *et al.*, 2015; Araminienė, V. and Varnagirytė-

Kabašinskienė, I., 2015). In contrast, however, sawfly defoliation resulted in a significant, though small, reduction in diameter growth at the lower of the two points examined along the stem height of young Scots pine (*Pinus sylvestris*) trees but a lack of response of

height growth (Nordkvist, M. *et al.*, 2020). Similarly, Chen, Z. *et al.*, (2002) reported a negative effect of western spruce budworm (*Choristoneura occidentalis*) defoliation on diameter, but not height, growth of Douglas-Fir seedlings (*Pseudotsuga menziesii*) while Quentin, A. G. *et al.*, (2010) found a decrease in height and diameter growth of *Eucalyptus globulus* seedlings in response to treatment with *Paropsisterna agricola*. There was a tendency for a decline in height and diameter

with a progressive increase to the highest level of simulated insect damage (Figure 1), hinting that an intensity of insect-defoliation much higher than those tested here may have a significant effect on the morphological traits in this species. Moreover, the presence, absence or magnitude of a response to insect-defoliation may be determined by other existing biotic and abiotic conditions (Wright, S. L. *et al.*, 1989).

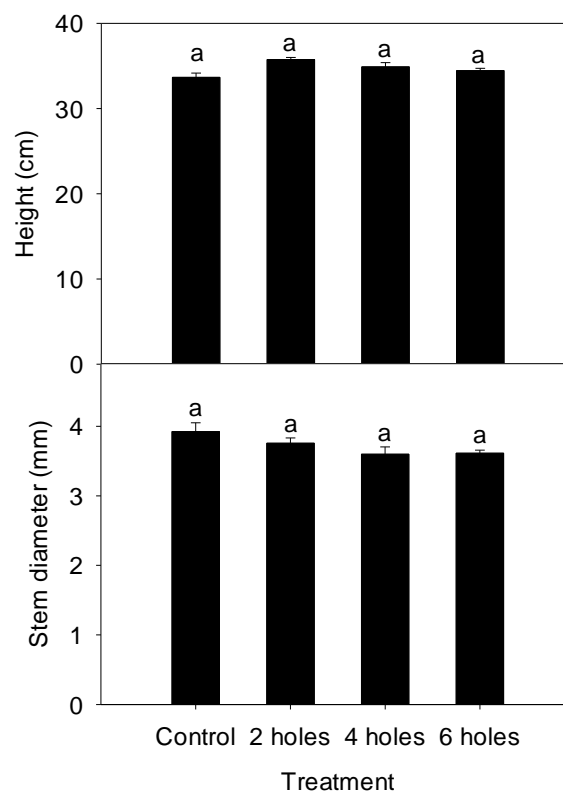


Figure 1: Effect of simulated insect damage on morphology

Unlike shoot biomass that was unresponsive, root and total biomass were significantly influenced by the simulated insect damage treatment (Table 1). The responses followed the same pattern, with a marked decline from the Control to the 4 holes and 6 holes perforated regimes which displayed comparable values of each trait. The observation that roots had a greater decline in biomass than shoots has been reported previously (Li, C. *et al.*, 2021). This did not, however, translate into a change in root/shoot ratio (Figure 2), suggesting that the defoliation treatment was not stressful enough to alter the flow of assimilates between the aboveground and belowground

plant fractions. In addition, the differences between the 2 holes perforated treatment and Control were not statistically significant (Figure 2). Such compensation of biomass but also morphological growth parameters, attributable to up-regulation of photosynthetic rate, has been frequently observed in plants subjected to natural and artificial defoliation (Trumble, J. T. *et al.*, 1993; Pinkard, E. A. and Beadle, C. L., 1998; Pinkard, E. A., 2003; Turnbull, T. L. *et al.*, 2007; Quentin, A. G. *et al.*, 2010). Similar to our finding, it took 67% and 99% defoliation to induce a decline in total biomass production, stem diameter, and stem volume of sweetgum (*Liquidambar styraciflua*) from a Control

treatment that did not differ significantly from a 33% defoliation class for any of the

variables (Jetton, R. M. and Robison, D. J., 2014).

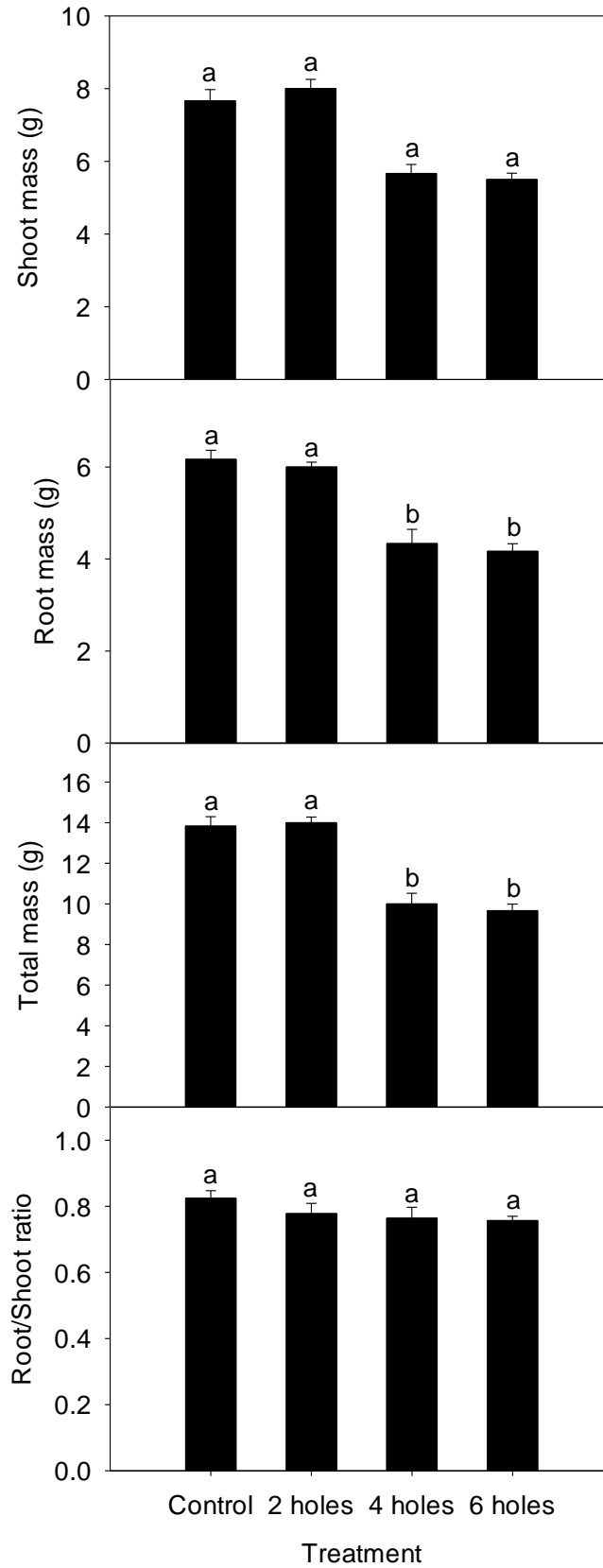


Figure 2: Effect of simulated insect damage on biomass

Conclusion

The findings of this study suggest that gmelina may be tolerant to insect damage of low intensity. Where a high-density insect outbreak that could potentially result in severe leaf tissue damage is anticipated, efforts to control insect populations through chemical or other means may be necessary to avoid growth and productivity declines. Caution should be taken, however, in the application of the results as there are potential differences between simulated and natural insect damage in terms of the stress imposed. While reducing the photosynthetic surface area, feeding insects may additionally inject salivary components with phytotoxic or enzymatic activity that can induce biochemical reactions leading to further damage of the host plant (Tan. *et al.*, 2015). Nevertheless, the data provides fundamental insights on the effects of insect damage on the growth of gmelina as a basis for modelling and developing appropriate control measures.

Acknowledgements

This work was financially supported by a Research Modernization Allowance of the Cameroonian Ministry of Higher Education. We are grateful to RETAFO for logistical support.

References

1. Niinemets, U. "Responses of forest trees to single and multiple environmental stresses from seedlings to mature plants: past stress history, tolerance and acclimation." *Forest Ecology and Management* 260.15 (2010): 1623-1639.
2. Jacquet, J. S., Christophe, O. and Hervé, J. "Defoliation by processionary moth significantly reduces tree growth: a quantitative review." *Annals of Forest Science* 69.8 (2012): 857-866.
3. Jacquet, J. S., Alexandre, B., Anthony, O. and Hervé J. "Combined effects of defoliation and water stress on pine growth and non-structural carbohydrates." *Tree Physiology* 34.4 (2014): 367-376.
4. Day, T. A., Scott, A. H. and Evan, H. D. "Limitations of photosynthesis in *Pinus taeda* (Loblolly pine) at low soil temperatures." *Plant Physiology* 95.4 (1991): 1246-1254.
5. Dang, Q. L. and Song, C. "Effects of soil temperature on ecophysiological traits in seedlings of four boreal tree species." *Forest Ecology and Management* 194.1-3 (2004): 379-387.
6. Ambebe, T. F., Qing-Lai, D. and Junlin L. "Low soil temperature inhibits the effect of high nutrient supply on photosynthetic response to elevated carbon dioxide concentration in white birch seedlings." *Tree Physiology* 30.2 (2010): 234-243.
7. Grossnickle, S. C. "Ecophysiology of northern spruce species: the performance of planted seedlings." NRC Research Press, Ottawa (2000): 1-407.
8. Onwuka, B. M. "Effects of soil temperature on Some Soil properties and plant growth." *Scholarly Journal of Agricultural Science* 6.3 (2016): 89-93.
9. Kitao, M., Evgenios, A., Kenichi, Y., Masabumi, K., Satoshi, K. and Hiroyuki, T. "Growth and photosynthetic responses of seedlings of Japanese white birch, a fast-growing pioneer species, to free-air elevated O₃ and CO₂." *Forests* 12.6 (2021): 675.
10. Ambebe, T. F., and Qing-Lai, D. "Low moisture availability inhibits the enhancing effect of increased soil temperature on net photosynthesis of white birch (*Betula papyrifera*) seedlings grown under ambient and elevated carbon dioxide concentrations." *Tree Physiology* 29.11 (2009): 1341-1348.
11. Seidl, R., Paulo, M. F., Teresa, F. F., François, G., Anna, M. J., Katarína, M., Sigrid, N., A. Arpacı., Bontemps, J. D., H. Bugmann., Gonzalez-Olabarria, J. R., P. Lasch., C. Meredieu., F. Moreira., Schelhaas, M. J. and F. Mohren. "Modelling natural disturbances in forest ecosystems: a review." *Ecological Modelling* 222. 4 (2011): 902-924.
12. Navarro, L., Hubert, M., Yves, B. and Miguel, M. G. "Changes in spatiotemporal patterns of 20th century spruce budworm outbreaks in eastern Canadian boreal forests." *Frontiers in Plant Science* 9 (2018): 1905.

13. Lavoie, J., Miguel, M. G. and Hubert, M. "Vulnerability of conifer regeneration to spruce budworm outbreaks in the Eastern Canadian boreal forest." *Forests* 10.10 (2019): 850.
14. Huttunen, L., Matthew, P. A., Pekka, N., Susanne, H., Riitta, T., Matti, R. and Seppo, K. "Interactive effects of defoliation and climate change on compensatory growth of silver birch seedlings." *Silva Fennica* 47.3 (2014): 964.
15. Mutikainen, P., Mari, W., Jari, O., Markku, K., Riitta, J. T. and Elina, V. "Herbivore resistance in *Betula pendula*: effect of fertilization, defoliation and plant genotype." *Ecology* 81.1 (2000): 49-65.
16. Varnagirytė-Kabašinskienė, I., Valda, A. and Vidas, S. "Effects of artificial defoliation and simulated insect damage on the growth of *Betula pendula* saplings." *iForest* 9.1 (2015): 95-100.
17. Helbig, C. E., Michael, G. M. and Dirk, L. "Effects of Leaf Loss by Artificial Defoliation on the Growth of Different Poplar and Willow Varieties." *Forests* 12.9 (2021): 1224.
18. Rogers, W. E. and Evan, S. "Effects of simulated herbivory and resource availability on native and invasive exotic tree seedlings." *Basic and Applied Ecology* 3.4 (2002): 297-307.
19. Zhao, W., Shi-Ping, C. and Guang-Hui, L. "Compensatory growth responses to clipping defoliation in *Leymus chinensis* (Poaceae) under nutrient addition and water deficiency conditions." *Plant Ecology* 196.1 (2008): 85-99.
20. Araminienė, V., and Iveta, V. K. "Birch growth responses to the insect injury simulations." In: *Proceedings of the 21st Annual International Scientific Conference Research for Rural Development 2* (2015): 56-60.
21. Li, C., Hugh, B., Bernard, R. and Robert, L. "Ecology and Prediction of Compensatory Growth: From Theory to Application in Forestry." *Frontiers in Plant Science* 12 (2021): 655417.
22. WWF. "Cameroon Highlands Forests - A Global Ecoregion." WWF (2017). <http://clonewwf.wwf-dev.org>.
23. Adam, K. A., and E. Krampah. "*Gmelina arborea* Roxb. ex Sm. [Internet] Record from PROTA4U." Louppe, D., Oteng-Amoako, A. A., and Brink, M. (Editors). PROTA (Plant Resources of Tropical Africa), Wageningen (2005). <http://www.prota4u.org/search.asp>. Accessed 18 March 2022.
24. Ashalatha, M., and K. Sankh. "Review article on gambhari (*Gmelina arborea* Linn)." *Unique Journal of Ayurvedic and Herbal Medicines* 2.6 (2014): 12-16.
25. PROTA. PROTA4U web database, Wageningen, Netherlands: Plant Resources of Tropical Africa (2016). <http://www.prota4u.info>.
26. Jamieson, M. A., Amy, M. T., Kenneth, F. R. and Richard, L. L. "Consequences of climate warming and altered precipitation patterns for plant-insect and multitrophic interactions." *Plant Physiology* 160.4 (2012): 1719-1727.
27. Climate-Data.org. Climate Bamenda (Cameroon). <https://en.climate-data.org/africa/cameroon/northwest/bamenda-2905/>. Accessed 16 March 2022.
28. Data Description. "Data Desk, Version 6.01." Data Description, Ithaca, NY (1996).
29. Nordkvist, M., Maartje, J. K. and Christer, B. Interacting effects of insect and ungulate herbivory on Scots pine growth. *Scientific Reports* 10 (2020): 22341.
30. Chen, Z., Thomas, E. K. and Karen, M. C. "Effects of artificial and western spruce budworm (Lepidoptera: Tortricidae) defoliation on growth and biomass allocation of Douglas-fir seedlings." *Journal of Economic Entomology* 95.3 (2002): 587-594.
31. Quentin, A. G., Elizabeth, A. P., Christopher, L. B., Timothy, J. W., Anthony, P. O., Stephen, P. and Caroline, L. M. "Do artificial and natural defoliation have similar effects on physiology of *Eucalyptus globulus* Labill. seedlings?" *Annals of Forest Science* 67.2 (2010): 203.
32. Wright, S. L., Richard, W. H. and John, W. P. "Effect of simulated insect damage on growth and survival of northern red oak (*Quercus rubra* L.) seedlings." *Environmental Entomology* 18.2 (1989): 235-239.

33. Trumble, J. T., Kolodny-Hirsch, D. M., and Ting, I. P. "Plant compensation for arthropod herbivory." *Annual Review of Entomology* 38 (1993): 93-119.
34. Pinkard, E. A., and Beadle, C. L. "Effects of green pruning on growth and stem shape of *Eucalyptus nitens* (Deane and Maiden) Maiden." *New Forests* 15.2 (1998): 107-126.
35. Pinkard, E. A. "Physiological and growth responses related to pattern and severity of green pruning in young *Eucalyptus globulus*." *Forest Ecology and Management* 182.1-3 (2003): 231-245.
36. Turnbull, T. L., Mark, A. A. and Charles, R. W. "Increased photosynthesis following partial defoliation of field-grown *Eucalyptus globulus* seedlings is not caused by increased leaf nitrogen." *Tree Physiology* 27.10 (2007): 1481-1492.
37. Jetton, R. M. and Daniel, J. R. "Effects of artificial defoliation on growth and biomass accumulation in short-rotation sweetgum (*Liquidambar styraciflua*) in North Carolina." *Journal of Insect Science* 14 (2014): 107.
38. Tan, X., Xiuping, X., Yong, G., Qinmin, Y., Yunsheng, Z., Jiqing, W., Fanghao, W. and Hongxu, Z. "Levels of salivary enzymes of *Apolygus Lucorum* (Hemiptera: Miridae), from 1st instar nymph to adult, and their potential relation to bug feeding. *PloS One*, 11.12 (2016): e0168848.

Source of support: Cameroonian Ministry of Higher Education;

Conflict of interest: Nil.

Cite this article as:

Ambebe, T. F. and Lawrence, M. N. "Morphology and Biomass Traits of *Gmelina arborea* as Influenced by Simulated Insect Leaf Damage." *Annals of Plant Sciences*.11.04 (2022): pp. 5005-5012.

DOI: <http://dx.doi.org/10.21746/aps.2022.11.4.1>