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The Effect of Slope on Diameter and Height Growth of *Grevillea robusta* at Wondo Genet, Southern Ethiopia

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ABSTRACT

Grevillea robusta (A. Cunn. ex R.Br.) is widely used in Africa and grows on fairly well drained and neutral to acidic soils in altitude ranging 0-3,000 m a.s.l. but does not tolerate water logging or heavy clays. In Ethiopia, it does well in agro-climatic zones ranging 1,500-2,700 m a.s.l. In this study, three south facing slope categories with mean slope in degree and mean slope length in meters {(15, 50); (8, 70); (4, 100)} are selected coincidently in ten-year old *G. robusta* plantation perpendicular to the contour. Ten trees at each slope range are selected randomly. The objectives of the study were i) to identify the slope factor on height and Diameter at Breast Height (DBH *i.e.*1.3 m above the ground) growth of *G. robusta* trees and ii) to compare responses of apical and lateral growths of trees on three slope categories to give reasonable assurance of detecting meaningful differences. The statistical analysis from one-way ANOVA at $\alpha = 5\%$ has shown that there is highly significant difference ($P < 0.0001$) in height growth of *G. robusta* planted on different slope ranges. Similarly, it was also recognized that there is significant difference ($P < 0.04$) in lateral or diameter growth of *G. robusta* trees planted at hillsides of Abaro Mountain at Wondo Genet.

Keywords: apical growth, environmental conditions, lateral growth, measurements, plantation, slope variation, symmetrical growth

Abbreviations: ANOVA, analysis of variance; **CI**, confidence interval; **DBH**, diameter at breast height; **NRMRD-MOARD**, natural resource management and regulatory department of the ministry of agriculture and rural development; **SLU**, Swedish University of Agricultural Sciences; **SPSS**, Statistical Package for Social Scientists; **WGCFNR**, Wondo Genet College of Forestry and Natural Resources

INTRODUCTION

Grevillea robusta is the largest species in the genus *Grevillea*. It is a native of eastern coastal Australia, in riverine, subtropical and dry rainforest environments receiving more than 1,000 mm per year of average rainfall (Harwood 1990, 1998; Derraik and Rademaker 2009). It is almost naturalized in Ethiopia and grown in ornamental, coffee shade, along border and road side of tea plantation and in different agroforestry systems. As elaborated by several authors (Yasu 1999; Kalinganire *et al*. 2001; Tengnäs *et al.* 2007), it is widely used in Africa and grows on fairly well drained and neutral to acidic soils in altitude ranging 0-3,000 m a.s.l. but does not tolerate water logging or heavy clays. In Ethiopia, it does well in agro-climatic zones ranging 1,500-2,700 m a.s.l.

In broader ecological terms the effect of altitude on the growth of trees is commonly studied (Paulsen *et al*. 2000; Booth and Ekelem 2002; Coomes and Allen 2007). The treeline is the edge of the habitat at which trees are capable of growing. Beyond the treeline, they are unable to grow because of inappropriate environmental conditions – cold temperatures, insufficient air pressure, or lack of moisture. At the treeline, tree growth is often very stunted, with the last trees forming low, densely matted bushes (Peng *et al.* 2008; Zhang *et al.* 2009). However, studies on the effect of slope on tree growth within the same landscape of minimal varying slope is not well studied and not given due consideration. In Ethiopia, variations in slope within a short distance and their influences on plant growth are poorly understood as well (Barij *et al*. 2007).

All plants need sunlight, food, water, air and space in varying degrees to afford their growth and life cycle. Trees increase in diameter as a ring of many cells of xylem is laid down by division of the cambium layer (Husch *et al*. 2003). As framed by Mexal (2005), the rate of growth depends on many factors such as: species, spacing, overabundant rainfall or drought years and site quality. Height growth occurs by elongation from the terminal bud as well as twigs and branches go through the same process (Harmon 1941; McNab 1989; Meizer 2003; Punches 2004).

Several studies had shown that height and diameter growth are more affected by stand density. For instance, Woodruff *et al*. (2002) in their study had indicated that annual growth in the higher stocking densities decreases to a level below that of the lower densities. This shift is presumably caused by increasing intraspecific competition, which suppresses growth in the higher density stands. Other studies indicate that apical growth is insensitive to density and that radial growth increases with increased spacing (Seidel 1984; Lanner 1985). Not only height and diameter growth that could be affected by different factors but also asymmetrical growth is due to a combination of many factors of which no one can be said to be directly responsible. However, of these factors some are more important than others. The factors that show the greatest response in unsymmetrical growth are probably root position, slope and competition (Rao 2005; Gilman and Watson 2011). Of these three factors, root position combined with slope is the most important (Harmon 1941; Karanja *et al*. 1999; Auslander *et al*. 2003; McNab 2010). This study is, therefore, undertaken in ten years old *G. robusta* plantation planted with similar planting density at all the three slope ranges in the same climate.The objectives of the study is i) to recognize the slope factor on height and DBH growth of *G. robusta* trees and ii) to compare responses of apical and lateral growths of trees on three slope categories to give reasonable assurance of detecting meaningful differences.

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Short Communication

Table 1 ANOVA for height and DBH growth.

Parameter	Sources	Sum of Squares	df	Mean Square	F	p
Height	Between Groups	322.945	2	161.472	11.002	0.000**
	Within Groups	396.265	27	14.676		
	Total	719.210	29			
DBH	Between Groups	133.693	2	66.846	3.684	0.038*
	Within Groups	489.926	27	18.145		
	Total	623.619	29			

MATERIALS AND METHODS

Description of study site

Wondo Genet is geographically located at 38° 37' 48" E and 7° 5' 37" N with an altitude of 1800 m a.s.l. According to Natural Resource Management and Regulatory Department of the Ministry of Agriculture and Rural Development (NRMRD-MOARD 2005), the agro-ecological region of the area is characterized by Tepid humid mid highland (H3). According to rainfall data from Wondo Genet Meteorological station of the year 1991-2004, the average annual rainfall is 1372 mm. It has bi-modal rainfall pattern with extended rainy season from March to October. The peak rain seasons of the area are April (210 mm) and August (185 mm). The mean annual temperature is 19°C. The mean maximum and minimum annual temperature is 29 and 10°C, respectively.

Sampling approach and data analysis

Three south facing slope ranges with mean slope in degree and mean slope length in meters {(15, 50); (8, 70); (4, 100)} are selected coincidently in ten-year old *G. robusta* plantation perpendicular to the contour. The slope has been measured with Swedish made sunnto clinometers. Ten trees at each slope range are selected randomly and the respective height and DBH of each tree is measured by Swedish made handheld Suunto hypsometer and Mantax Precision Blue beam calliper (calibration of 50 cm) respectively. The data collected has been encoded thoroughly in SPSS-17 software package. After the raw data had been encoded one-way ANOVA was employed to analyze the variations among mean height and DBH and with regard to mean comparison, the Independent-Samples *t*-Test at $\alpha = 0.05$ was used to analyze the difference between treatment means.

RESULTS AND DISCUSSION

Effect of slope on height and diameter

The statistical analysis from one-way ANOVA at $\alpha = 5\%$ has shown that there is highly significant difference ($P < 0.0001$) in height growth of *G. robusta* planted on different slope ranges. Similarly it was also recognized that there is significant difference ($P < 0.04$) in lateral or diameter growth of *G. robusta* trees planted at hillsides of Abaro Mountain at Wondo Genet (**Table 1**).

In a micro-climate of smaller area with almost similar climatic, soil and management condition, it was recognized that, as the slope steepness is getting higher and higher the apical (height) and lateral (diameter) growth of *G. robusta* is decreasing, indicating the influence of slope factor (**Fig. 1A-D** – the error bars are displayed using standard error). The mean height at gentle slope is significantly taller than grown on the steeper slope and vice versa. A similar trend has been recorded for the diameter growth too.

In height growth of *G. robusta* at the hillside of Abaro Mountain it has been recognized from the independent samples *t*-test that there is highly significant difference of mean height in trees between slopes 4° vs. 15° and between 8° vs. 15° while there is no significant difference between 4° vs. 8° slopes. In the same analysis for the lateral growth, it has been found that there is significant difference in mean diameter growth of *G. robusta* between 4° vs. 15° slopes and

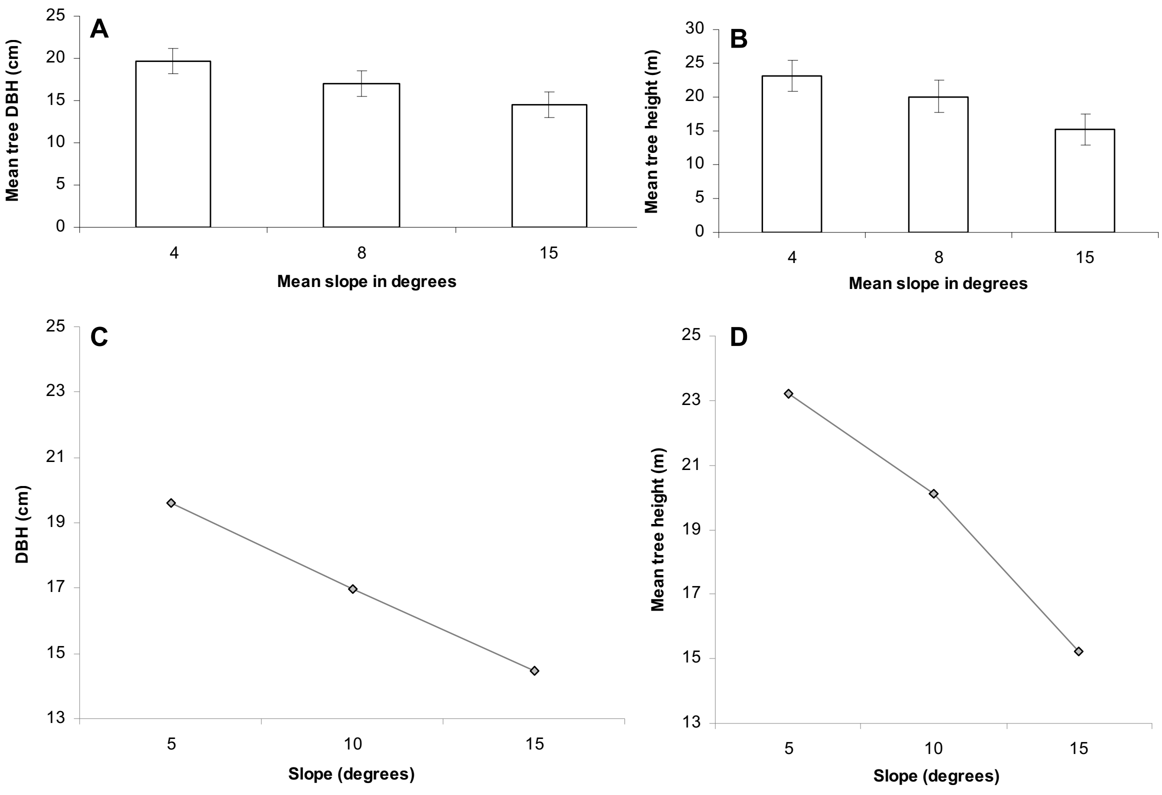

Fig. 1 Height and DBH variation due to slope factor.

Table 2 Comparison of mean height and diameter at 4°, 8° and 15° slopes using an Independent Samples Test.

Parameter	Treatment comparison	t	df	p	Mean difference	Std. error difference	95% CI of the difference
Height	4° vs. 15°	-4.827	18	**0.000****	-7.970	1.651	(-11.439, -4.501)
	8° vs. 15°	-2.996	18	**0.008****	-4.880	1.629	(-8.302, -1.458)
	4° vs. 8°	-1.669	18	0.112	-3.090	1.851	(-6.979, 0.799)
DBH	4° vs. 15°	-2.582	18	**0.019***	-5.170	2.002	(-9.376, -0.964)
	8° vs. 15°	-1.675	18	0.111	-2.500	1.492	(-5.635, 0.635)
	4° vs. 8°	-1.238	18	0.232	-2.670	2.157	(-7.201, 1.861)

Table 3 Statistical analysis of mean height and DBH at different slopes.

Parameter	Slope (°)	N	Mean	Std. Deviation	Std. Error Mean	CV (%)
Height (m)	15	10	15.220	3.125	0.988	6.49
	8	10	20.100	4.095	1.295	6.44
	4	10	23.190	4.183	1.323	5.70
DBH (cm)	15	10	14.450	2.813	0.890	6.16
	8	10	16.950	3.789	1.198	7.07
	4	10	19.620	5.671	1.793	9.14

no significant difference between 4° vs. 8° and 8° vs. 15° slopes (**Table 2**).

Tree diameter and height growth is sensitive to environmental variations and can influence forest community dynamics (Gilman *et al.* 1980; White 1981; Ren *et al.* 1998). In this study, both height and diameter growth of *G. robusta* trees were negatively correlated with slope at which the mean height is found more sensitive to slope variations than mean DBH. The lack of any significant differences in mean height of *G. robusta* trees on 4° vs. 8° slopes suggests that growth differences probably were not caused by a mechanism that operates primarily through changes in these minimal slope ranges. This is also holds true for the lack of significant differences in mean DBH between 4° vs. 8° and 8° vs. 15° slopes (**Table 2**). It reflects to reason that diameter growth is heavily influenced by other biotic and/or abiotic environmental factors than slope (Harmon 1941; Karanja *et al*. 1999; Auslander *et al*. 2003; McNab 2010). Rao (2005) and Gilman and Watson (2011) noted that root position combined with slope factor affected *G. robusta* diameter as well as height growth, parallel to the result of this study. The result from this study may help in the management plan in undertaking plantation projects which aim to produce high quality wood. Because slope factor has affected the growth of tree height and DBH (**Table 3**) which in turn in one way or another can affect symmetrical growth and wood quality.

CONCLUSION

It has been understood that knowledge of the growth responses of trees to factors of the environment is important to forest management. In doing so, the forest practitioner can use this knowledge to encourage the establishment and growth of desirable species by concentrating on sites having desirable characteristics. In this study, even if the primary objective is the study of slope factor of the site, it has done with the recognition of the effect of other factors at least at minimum level. This study has shown that the more the steeper is the slope the lower height and DBH growth of *G. robusta* trees in this particular study site.

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REFERENCES

Auslander M, Nevo E, Inbar M (2003) The effects of slope orientation on plant growth, developmental instability and susceptibility to herbivores. *Journal of Arid Environments* **55**, 405-416

Barij N, Stokes A, Bogaard T, Beek RV (2007) Does growing on a slope affect tree xylem structure and water relations? *Tree Physiology* **27**, 757-764

Booth HT, Ekeleme F (2002) Identifying climatically suitable areas of growing particular trees in Africa: An example using *Grevillea robusta*. *Agroforestry Systems* **54 (1)**, 41-49

Coomes DA, Allen RB (2007) Effect of size, competition and altitude on tree growth. *Journal of Ecology* **95**, 1084-1097

Derraikl JGB, Rademaker M (2009) Allergic contact dermatitis from exposure to *Grevillea robusta* in New Zealand. *Australasian Journal of Dermatology* **50**, 125-128

Gilman EF, Leone I, Flower FB (1980) Factors affecting tree growth on resource recovery residual landfills. In: *Proceedings of the National Waste Processing Conference*, May 11-14, Environmental Protection Agency, USA, pp 147-153

Gilman EF, Watson DG (2011) *Grevillea robusta*: Silk-Oak. Environmental Horticulture, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. ENH444, UF, IFAS Extension. Available online: http://edis.ifas.ufl.edu

Harwood CE (1990) Provenance Collections of *Grevillea robusta* (silky oak). *Forest Genetic Resources Information* No. 18, Food and Agricultural Organization of the United Nations. Available online: www.fao.org/docrep/006/u2240E04.htm#ch4

Hardwood CE (1998) *Grevillea robusta – A Versatile and Popular Tree for Farm Forestry*. Forest, Farm, and Community Tree Network (FACT Net), Winrock International, Morrilton. Available online: www.winrock.org/fnrm/factnet/factpub/factsh/grevillea.htm

Harmon M (1941) A study of some growth factors affecting asymmetrical growth in trees. *Butler University Botanical Studies* **5 (1)**, 134-144

Husch B, Beers TW, Kershaw J (2003) *Forest Menstruation* (4th Edn), John Wiley & Sons, Inc., Hoboken, New Jersey, 443 pp

Kalinganire A, Harwood CE, Slee MU, Simons AJ (2001) Pollination and fruit-set of *Grevillea robusta* in western Kenya. *Austral Ecology* **2**, 637-648

Karanja NK, Mwendwa KA, Zapata F (1999) Growth response of *Grevillea robusta* A. Cunn. seedlings to phosphorus fertilization in acid soils from Kenya. *Biotechnology, Agronomy, Society and Environment* **3 (1)**, 57-64

Lanner RM (1985) On the insensitivity of height growth to spacing. *Forest Ecology and Management* **13**, 143-148

McNab WH (1989) Terrain Shape Index: Quantifying effect of minor landforms on tree height. *Forest Science* **35 (1)**, 91-104

McNab WH (2010) *Topography, Soils and Trees: How The Land Affects the Forest Type*, US Forest Service bent Creek Experimental Forest, Asheville, NC, Woodland Steward Series, 18 pp

Meinzer FC (2003) Functional convergence in plants' responses to the environment. *Oecologia* **134**, 1-11

Mexal JG (2005) *Forestry and Society*: *How a Tree Grows*. PowerPoint presentation, 50 pp Available online: www.slidefinder.net/h/hort_20302_20how_20a_20tree/25759700

NRMRD-MOA (Natural Resource Management and Regulatory Department of the Ministry of Agriculture and Rural Development) (2005) *Agro-ecological Map of Ethiopia*, Addis Ababa

Paulsen J, Weber UM, Körner C (2002) Tree growth near treeline: Abrupt of gradual reduction with altitude? *Arctic, Antarctic and Alpine Research* **32 (1)**, 14-20

Peng J, Gou X, Chen F, Li J, Liu P (2008) Difference in tree growth responses to climate at the upper treeline: Qilian juniper in the Anyemaqen Mountains. *Journal of Integrative Plant Biology* **50 (8)**, 982-990

Punches J (2004) *Tree Growth, Forest Management, and Their Implications for Wood Quality*, Oregon State University, Extension Publication, 8 pp

Rao PB (2005) Effect of shade on seedling growth of five important tree species in Tarai Region of Uttaranchal. Ecology and environmental management: Issues and research needs. *Bulletin of the National Institute of Ecology* **15**, 161-170

Ren Q, Chai Y, Wang J (1998) Effect of slope on growth of three hard broad-leaved tree species in Northeast China. *Journal of Forestry Research* **9 (1)**, 27-30

Seidel KW (1984) A western larch – Engelmann spruce spacing study in eastern Oregon: results after 10 years. *USDA Forest Service Research Note PNW-409*

Tengnäs B, Ensermu K, Sebsibe D, Maundu P (Eds) (2007) *Useful Trees and Shrubs of Ethiopia: Identification, Propagation and Management for 17 Agroclimatic Zones*. World Agroforestry Centre, East Africa Region, Nairobi Kenya, 550 pp

WGCF–NR (Wondo Genet College of Forestry and Natural Resources) (2006) Wondo Genet Meteorological Station, Wondo Genet, Ethiopia. Available online: www.wgcf-nr.org

White EJ (1981) Site factors influencing the growth of stands of Scots pine in Great Britain. In: Last FT, Gardiner AS (Eds) *Forest and Woodland Ecology: An Account of Research Being Done in ITE.* Cambridge, NERC/Institute of Terrestrial Ecology, pp 49-53

Woodruff DR, Bond BJ, Ritchie GA, William SW (2002) Effects of stand density on the growth of young Douglas-fir trees. *Canadian Journal of Forestry Research* **32**, 420-427

Yasu H (1999) The diffusion process of planting *Grevillea robusta* among rural households in North-Central Tanzania. *African Study Monographs* **20 (3)**, 119-145

Zhang Q, Zhang Y, Peng S, Yirdaw E, Wu N (2009) Spatial structure of alpine trees in Mountain Baima Xueshan on the Southeast Tibetan Plateau. *Silva Fennica* **43 (2)**, 197-208