

**ECOLOGY AND PHENOTYPIC VARIATIONS OF *VITELLARIA PARADOXA*  
SUBSPECIES *NILOTICA* (KOTSCHY), A.N. HENRY *ET AL.* IN ETHIOPIA**

**By**

**DERIBE GURMU BENTI**

**Thesis Submitted To the School of Graduate Studies, Universti Putra  
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**April 2005**

## DEDICATION

To my mother w/o Mekoya Gebre, my wife, Sinedu Berhane Yenesu, our children Simerete, Hanna, Liyate and Hemene, my brothers and sister and their families, GOD blesses them all!

ABSTRACT of the thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for Doctor of Philosophy

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**April 2005**

**Chairman: Associate Professor Nor Aini Ab. Shukor, PhD**

**Faculty: Forestry**

The ecology and the phenotypic variations of *Vitellaria paradoxa* (Gaertner f.), a multipurpose tree, highly valued for its oil was studied in Gambella region: Ethiopia. The objective of the study was to examine the ecology and the phenotypic variations between and within the natural population of *Vitellaria paradoxa*. The sections under ecological studies were done through inventory of the woodland based on random sampling method, in green house and in laboratories while the phenotypic variations were analyzed based on morphological traits. Results from population survey of 46 ha of woodland consisting of 230 quadrats showed that *Vitellaria paradoxa* accounted for 9.9% of the total trees and its basal area was estimated at  $1.68 \text{ m}^2 \text{ ha}^{-1}$ , representing an 30.15% of the total cover. There were significant differences, at  $P < 0.05$ , in terms of mean diameter at breast height, height and basal area between the populations. The total stocking rate was estimated only at  $18 \text{ trees ha}^{-1}$  and estimation of the diameter class of the species showed that 48.54% of the trees had diameters lying above the mean. The recruitments were estimated at 22

seedlings  $\text{ha}^{-1}$  and the species demography was also not encouraging as the ratio between the matured trees and the recruitments were approximately equal (1:1). There were also no viable seeds of *Vitellaria paradoxa* found in the soil seed bank. The soil seed bank was dominated by grasses (43%) and sedge (22%) and there was no correspondence between the seed bank regenerations and the natural populations particularly for trees and shrubs. The regeneration trend showed that the population of *Vitellaria* was threatened.

The soil analysis result showed that the species requires medium textured soil and  $\text{pH} < 6$  and the foliar analysis result depicted that the species was not deficient in nutrients. The indicator value of the species was 53.8% and it occurred in more than half of the quadrats and its pattern of distribution was much influenced by elevation gradient.

There were variations in the main mean tree characteristics such as crown diameter, basal area, diameter at breast height and height and the major mean leaf characteristics such as petiole length, total leaf length, lamina width and petiole ratio along the altitudinal gradient and the variation in crown diameter and lamina width was highly significant at  $P < 0.05$ . Small sizes of leaves and petiole lengths were found in Elia and larger sizes of leaves and petiole lengths were recorded in Abbot and Phugnido. Medium size leaves and petiole lengths were registered in Agnota. Similarly, short trees with smaller diameters were found in Elia, tall trees with spreading crown and bigger diameter were found in Abbot and

Phugnido and taller trees with prominent crowns were concentrated in Agnota. Cluster analysis of the six qualitative traits also showed the close relatedness of the four populations where Abbot and Phugnido formed one cluster and Agnota and Elia formed clusters of their own.

The allometric relationships between mean tree parts and the mean leaf characteristics and the mean leaf characteristics with each other were also significant at  $P < 0.05$ . For instance, diameter at breast height (dbh) was strongly related to the basal area (ba), ( $dbh = 0.988ba + 1.128$ ,  $r^2 = 0.976$ ), basal area (ba) was strongly related to the crown diameter (cd), ( $ba = 0.542cd + 0.116$ ,  $r^2 = 0.288$ ).

Among tree characteristics, only crown diameter was related to lamina width (lw), and petiole ratio (pr), ( $cd = 0.396lw + 0.436pr + 1.605$ ,  $r^2 = 0.150$  (lw),  $r^2 = 0.176$  (pr)). All the major leaf characteristics were also strongly and positively related with each other. For example, petiole length (pl) was strongly related with total leaf length (tll) ( $pl = 0.818tll + 0.310$ ,  $r^2 = 0.669$ ), lamina length (ll) was strongly related with total leaf length (tll), ( $ll = 0.954tll + 0.690$ ,  $r^2 = 0.909$ ) and lamina width (lw) was strongly related to leaf ratio (lr) ( $lw = 0.711lr + 11.992$ ,  $r^2 = 0.502$ ).

The cluster membership result showed a random distribution of the trees from one eco-geographical region to the other. For example, groups 81, 82, and 84 were found in all the four populations, group 87 was found in two populations

(Abbot & Elia), groups 83 and 88 were found in three populations (Abbot, Elia and Phugnido) while group 85 was found only in Elia.

The variations in the traits, that formed the cluster groups, were explained by four axes that accounted for 77% of the variance in the sampled trees by quantitative traits matrix of the sampled plots. In general, the phenotypic variation result showed that the in between population variation was higher than within population variation for the quantitative traits and this phenotypic variation due to in between populations was 86.52%. Similarly, the in between populations variation was higher than the within population variation in terms of the qualitative traits and the percentage of the phenotypic variance due to within population accounted for 92.61%. Thus, based on the total trend in the demography of the species and the location of the variations, two complimentary strategies are suggested, firstly, *in-situ* conservation approach involving as many populations as possible should be considered since there are high inter population variation, secondly, *ex-situ* conservation involving as many selected individuals within a group from all cluster groups should be undertaken concurrently as there are high inter population variations to reserve as well as to initiate improvement program for *Vitellaria paradoxa* ssp. *nilotica*.

ABSTRAK tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi untuk Ijazah Doktor Falsafah

**EKOLOGI DAN VARIASI PHENETIK *VITELLARIA PARADOXA* SUBSPECIES  
*NILOTICA* (KOTSCHY), A.N. HENRY *ET AL.* DI ETHIOPIA**

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Ekologi dan variasi phenetik *Vitellaria paradoxa* (Gaertner f.), suatu pokok pelbagaiguna yang mana minyaknya dihargai telah dikaji di kawasan Gambella, Ethiopia. Objektif penyelidikan ini adalah untuk mengkaji ekologi dan variasi phenetik di dalam dan di antara populasi semulajadi *V. paradoxa*. Kajian ekologi telah dijalankan secara inventori pada kawasan hutan terbuka menggunakan kaedah persampelan rawak di lapangan, rumah kaca dan di makmal. Manakala ciri morfologi telah digunakan untuk analisis phenetik variasi. Keputusan daripada kajiselidik populasi bagi 48 ha kawasan hutan terbuka "woodland" yang mengandungi 230 kuadrat menunjukkan bahawa 9.9% daripada jumlah pokok adalah *V. paradoxa* dan keluasan pangkal dianggarkan pada kadar 1.68m<sup>2</sup>/ha yang mana kesemuanya mewakili 30.15% jumlah kawasan litupan hutan. Terdapat perbezaan yang bererti pada  $p < 0.05$  di antara populasi dari segi diameter perepang paras dada, ketinggian dan keluasan pangkal. Jumlah kadar pengisian dianggarkan sebanyak 18 pokok bagi setiap hektar dan menunjukkan

bahawa sebanyak 48.54% pokok mempunyai diameter melebihi daripada nilai purata. Anak pokok dianggarkan sebanyak 22 anak pokok bagi setiap hektar dan kajian demografi spesies adalah tidak mengalakkan kerana nisbah pokok matang dan anak pokok adalah bersamaan 1:1. Sebagai tambahan, tiada biji benih *V. paradoxa* yang hidup dalam biji benih tersimpan dalam tanah. Biji benih tersimpan dalam tanah didominasi oleh rumput (43%) dan tumbuhan "sedge" (22%), dan ianya juga menunjukkan tiada berkaitan di antara regenerasi bijibenih tersimpan dalam tanah dengan populasi semulajadi terutamanya pokok dan jaras. Corak regenerasi menunjukkan populasi *Vitellaria paradoxa* berada dalam keadaan yang membimbangkan.

Keputusan daripada analisis tanah menunjukkan bahawa spesies ini memerlukan tanah yang bertekstur sederhana dan  $\text{pH} < 6$ . Nilai petunjuk bagi spesies ini adalah 53.8% dan ia berlaku di dalam lebih dari separuh daripada jumlah kuadrat. Pola taburan spesies ini adalah sangat dipengaruhi oleh faktor altitud.

Terdapat variasi dalam ciri utama pokok seperti diameter silara, keluasan pangkal, diameter perepang paras dada dan ciri utama daun seperti panjang petiol, jumlah panjang daun, lebar lamina dan nisbah petiol sepanjang kecerunan altitud. Sebagai contoh, variasi diameter silara dan lebar lamina didapati mempunyai perbezaan yang bererti pada  $p < 0.05$ . Sais daun dan panjang petiol yang kecil diperolehi di kawasan Elia manakala sais yang besar telah



direkodkan di kawasan Abbot dan Phugnido. Sais daun dan panjang petiol yang sederhana dicerap di kawasan Agnota. Sementara itu juga, pokok yang tinggi dan berdiameter kecil diperolehi di Elia. Pokok pendek dengan bersilara melebar luas diperolehi di Abbot dan Agnota manakala pokok tinggi dengan berdiameter besar dan bersilara melebar luas tertumpu di kawasan Phugnido. Analisis kelompok bagi enam ciri kualitatif juga menunjukkan perkaitan yang rapat di kalangan empat populasi di mana Abbot dan Phugnido membentuk satu kelompok, manakala Agnota dan Elia membentuk kelompok tersendiri yang berbeza.

Hubungkait di antara bahagian pokok dan ciri daun dan ciri daun dengan satu sama lain adalah bererti pada  $p < 0.05$ . Sebagai contoh, diameter perepang paras dada adalah berkaitan kuat dengan keluasan pangkal ( $ba$ ) –  $dbh = 0.988ba + 1.128$ ,  $r^2 = 0.976$ , keluasan pangkal pula mempunyai perkaitan kuat dengan diameter silara ( $cd$ ) –  $ba = 0.542cd + 0.116$ ,  $r^2 = 0.288$ . Di antara ciri pokok yang dikaji, hanya diameter silara ( $cd$ ) yang mempunyai hubungkait dengan ciri daun seperti lebar lamina ( $lw$ ) dan kadar petiol ( $pr$ ) –  $cd = 0.396lw + 0.436pr + 1.605$ ,  $r^2 = 0.150(lw)$ ;  $r^2 = 0.176(pr)$ . Kesemua ciri utama daun juga menunjukkan perkaitan yang kuat dan positif di antara satu sama lain. Sebagai contoh, panjang petiol ( $pl$ ) adalah berkait rapat dengan jumlah panjang daun ( $tll$ ) –  $pl = 0.818tll + 0.310$ ,  $r^2 = 0.669$ , panjang lamina ( $ll$ ) adalah berkait kuat dengan jumlah panjang daun ( $tll$ ) –  $ll = 0.954tll + 0.690$ ,  $r^2 = 0.909$ ; dan lebar

laminar ( $lw$ ) adalah sangat berkaitan dengan nisbah daun ( $lr$ ) –  $lw = 0.771lr + 11.992$ ,  $r^2 = 0.502$ .

Keputusan analisis keahlian kelompok menunjukkan bahawa taburan pokok adalah secara rawak di dalam kawasan yang bereko-geografi yang berlainan dan boleh dikelompokkan dalam lapan kumpulan. Sebagai contoh, kumpulan 81, 82 dan 84 boleh terdapat dalam kesemua empat populasi, kumpulan 87 terdapat dalam dua populasi iaitu Abbot dan Agnota, kumpulan 88 terdapat dalam tiga populasi iaitu Abbot, Agnota dan Phugnido manakala kumpulan 85 hanya terdapat dalam Elia. Analisis komponen asas (PCA) kumpulan kelompok ini menunjukkan bahawa sebanyak 77% varian pokok yang disampel boleh diterangkan oleh empat komponen/ paksi.

Umumnya, kajian variasi genetik menunjukkan bahawa variasi antara populasi adalah lebih tinggi daripada variasi dalam populasi untuk ciri kuantitatif manakala variasi dalam populasi adalah lebih tinggi berbanding dengan variasi di antara populasi untuk ciri kualitatif. Variasi untuk ciri kuantitatif yang disebabkan oleh antara populasi adalah sebanyak 86.52% manakala variasi ciri kualitatif yang disebabkan oleh variasi dalam populasi adalah sebanyak 92.61%. Oleh itu berdasarkan kepada keseluruhan corak demografi spesies dan terdapatnya variasi ke atas lokasi, dua strategi boleh dicadangkan untuk aktiviti pemuliharaan dan pembiakan spesies ini. Pertama, secara pemuliharaan *in situ* di mana patut melibatkan kesemua populasi yang mungkin kerana terdapat variasi antara

populasi yang tinggi. Kedua adalah secara pemeliharaan *ex situ* iaitu dengan melibatkan beberapa individu pokok terpilih dalam kumpulan yang mewakili kesemua kumpulan kelompok yang terhasil kerana terdapatnya variasi dikalangan individu di dalam populasi yang tinggi. Walaubagaimana pun pemilihan ciri adalah bergantung dengan objektif program pembaikbiakan bagi *Vitellaria paradoxa* spp. *nilotica*

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I certify that an examination committee met on 22<sup>nd</sup> April 2005 to conduct the final examination of Deribe Gurmu Benti on his Doctor of Philosophy thesis entitled "Ecology and Phenotypic Variations of *Vitellaria paradoxa* Subspecies *Nilotica* (Kotschy), A.N. Henry *et al.* In Ethiopia" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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## DECLARATION

I hereby declare that the thesis is based on my original work except for the quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted to any other degree at UPM or other institution.

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