RESSALVA

Atendendo a solicitação do autor, o texto completo desta tese será disponibilizado somente a partir de 14/11/2025.

SÃO PAULO STATE UNIVERSITY "JÚLIO DE MESQUITA FILHO"
ENGINEERING FACULTY
CAMPUS DE ILHA SOLTEIRA

JORGE MANUEL REVILLA CHÁVEZ

STUDY OF POPULATION STRUCTURE, MOLECULAR CHARACTERIZATION OF *Aniba roseadora* (Ducke) ROSEWOOD IN AREAS OF POTENTIAL DISTRIBUTION OF MASISEA DISTRICT, UCAYALI, PERU

Ilha Solteira, São Paulo
2024

GRADUATE PROGRAM IN AGRONOMY

JORGE MANUEL REVILLA CHÁVEZ

STUDY OF POPULATION STRUCTURE, MOLECULAR CHARACTERIZATION OF *Aniba roseadora* (Ducke) ROSEWOOD IN AREAS OF POTENTIAL DISTRIBUTION OF MASISEA DISTRICT, UCAYALI, PERU

Thesis presented to the Faculty of Engineering of the Ilha Solteira Campus – UNESP as part of the requirements to obtain the title of Doctor in Agronomy. Specialty: Production System.

Orientador: Prof. Dr. Alexandre Magno Sebbenn

Ilha Solteira, São Paulo

2024

FICHA CATALOGRÁFICA
Desenvolvido pelo Serviço Técnico de Biblioteca e Documentação

R454s

Revilla Chávez, Jorge Manuel.
Study of population structure, molecular characterization of Aniba roseadora (Ducke) rosewood in areas of potential distribution of Masisea district, Ucayali, Peru / Jorge Manuel Revilla Chávez. -- Ilha Solteira: [s.n.], 2024
135 f. : il.

Tese (doutorado) - Universidade Estadual Paulista. Faculdade de Engenharia de Ilha Solteira. Área de conhecimento: Sistemas de Produção, 2024

Orientador: Alexandre Magno Sebbenn

Inclui bibliografia

1. Forest. 2. Rosewood. 3. Population density. 4. Population structure. 5. Seedling dispersal.

Amanda Sertori dos Santos
Bibliotecária - CRB/8-9061
Seção Técnica de Referência, Atendimento ao Usuário e Documentação
Diretoria Técnica de Biblioteca e Documentação

IMPACTO POTENCIAL DESTA PESQUISA

O pau-rosa *Aniba rosaeodora* Ducke, conhecido como “pau-rosa”, é uma espécie valiosa da Amazônia, que foi submetida a intensa exploração, que dizimou suas populações naturais, levando-a à beira da extinção e da degradação de sua diversidade genética. o presente estudo tem potencial para conservação e domesticação da espécie na Amazônia peruana que pode ser replicado no restante da Amazônia. As informações geradas podem traçar um plano de melhoramento genético da espécie, utilizando germoplasma de árvores de populações menos aparentadas, com base em padrões de dispersão de sementes e observando a composição de sua estrutura populacional. Da mesma forma, a pesquisa pode implementar uma base de sementes com aumento da diversidade genética para o manejo sustentável da floresta e o desenvolvimento de plantações comerciais em solos degradados da Amazônia, para a geração de renda econômica para os agricultores amazônicos, o que seria conter a expansão das fronteiras agrícolas na Amazônia.

POTENTIAL IMPACT OF THIS RESEARCH

The rosewood *Aniba rosaeodora* Ducke, known as "rosewood", is a valuable species of the Amazon, which was subjected to intense exploitation, which decimated its natural populations, bringing it to the brink of extinction and the degradation of its genetic diversity, so the present study has the potential for conservation and domestication of the species in the Peruvian Amazon, which can be replicated in the rest of the Amazon. The information generated can design a genetic improvement plan for the species, using germplasm from trees from less related populations, based on seed dispersal patterns and observing the composition of its population structure. Likewise, the research can implement a seed base with an increase in genetic diversity for sustainable forest management and the development of commercial plantations on degraded soils in the Amazon, to generate economic income for Amazonian farmers, which would contain the expansion of agricultural frontiers in the Amazon.

unesp

UNIVERSIDADE ESTADUAL PAULISTA

Câmpus de Ilha Solteira

CERTIFICADO DE APROVAÇÃO

TÍTULO DA TESE: ESTUDO DA ESTRUTURA POPULACIONAL, CARACTERIZAÇÃO MOLECULAR DE Aniba roseadora (Ducke) PAU-ROSA EM ÁREAS DE DISTRIBUIÇÃO POTENCIAL DO DISTRITO DE MASISEA, UCAYALI, PERU

AUTOR: JORGE MANUEL REVILLA CHÁVEZ
ORIENTADOR: ALEXANDRE MAGNO SEBBENN

Aprovado como parte das exigências para obtenção do Título de Doutor em Agronomia, área: Sistemas de Produção pela Comissão Examinadora:

Prof. Dr. ALEXANDRE MAGNO SEBBENN (Participaçao Virtual)
Genetica e Melhoramento Florestal / Instituto Florestal de Sao Paulo

Prof. Dr. CARLOS ABANTO RODRIGUEZ (Participaçao Virtual)
Diretoria de Pesquisa em Manejo Florestal e Serviços Ecossistêmicos / Instituto de Pesquisa da Amazônia Peruana

Prof. Dr. ENES FURLANI JUNIOR (Participaçao Virtual)
Departamento de Fitotecnia, Tecnologia de Alimentos e Socio Economia / Faculdade de Engenharia de Ilha Solteira - UNESP

Dr. DENNIS DEL CASTILLO TORRES (Participaçao Virtual)
Diretoria de Pesquisa em Manejo Florestal e Serviços Ecossistêmicos / Instituto de Pesquisa da Amazônia Peruana

Prof. Dr. JORGE ARTURO MORI VÁSQUEZ (Participaçao Virtual)
Departamento de Manejo Florestal / Universidade Nacional de Ucayali

Ilha Solteira, 14 de novembro de 2024

DEDICATION

To my wife Mayra, for her love, patience and understanding.

To my children Luciana, Jorge and Mayra; lights of my life and hope for tomorrow.

To my dear parents, Sadith and Jorge, for the love and effort to make me a better man, life will not be enough to thank.

ACKNOWLEDGEMENTS.

I thank God for taking care of my family at all times and especially during my absence to complete my doctorate.

To the São Paulo State University "Júlio de Mesquita Filho" (UNESP), Ilha Solteira Campus, Graduate Program in Agronomy, for the opportunity to take the Doctorate course.

To the Peruvian Amazon Research Institute (IIAP) and the World Agroforestry Center (ICRAF), for providing the information and logistics necessary for the development of this study.

My deep gratitude to Prof. Dr. Alexandre Magno Sebbenn, for the guidance, dedication and friendship in carrying out this work, without him I would not have achieved the objectives.

To Dr. Ananda Virginia de Aguillar, Dr. Mario Luiz Texeira de Moraes, Dr. Miguel Luiz Menezes Freitas and Dr. Liliane Santos de Camargos, for their support and guidance in carrying out the Doctorate course.

To the members of the examining board, for accepting the invitation to participate in the doctoral defense board.

The present work was carried out with the support of the Coordination for the Improvement of Higher Education Personnel – Brazil (CAPES DS: 01/06/2021 TO 29/02/2024) – Financing Code 001.

To all those who directly and indirectly contributed to the realization of this work, I am deeply grateful.

Thank you very much!

ABSTRACT

Aniba rosaeodora Ducke, known as "rosewood", is one of the most valuable tree species in the Amazon, famous for its linalool-rich essential oil, used in the cosmetics industry. However, their overexploitation has led to the decrease of their natural populations, affecting their production and genetic diversity, putting the species at risk of extinction. The species is found mainly in forests in Brazil, Colombia, Ecuador, Peru and other countries in the Amazon region, growing in habitats of plateaus and streams, and can reach up to 30 m in height. Seed dispersal depends on animals such as parrots and toucans, but their natural regeneration is threatened by predation and other factors. This study seeks to better understand the patterns of dispersion, density and population dynamics of *A. rosaeodora* in the Peruvian Amazon, in order to propose strategies for its conservation and forest management. Population dynamics play a key role in the conservation and domestication of species. From genetic assays of forest species in the Peruvian Amazon, methodologies were developed to evaluate the phenotypic variation of their traits of commercial interest. These methodologies were applied in conservation and domestication studies, through stability, adaptability and productivity tests of progenies of *Guazuma crinita* Mart, in addition to the qualitative and quantitative control of phenotypes of *Calycophyllum spruceanum* Benth. These studies, carried out in the Aguaytía river basin in the Peruvian Amazon, can be adapted for methodological application in *Aniba rosaeodora* Ducke in the region, with the aim of promoting its conservation and sustainable management.

Keywords: amazon forest, rosewood, population density, population structure, seedling dispersal, biomass, allometric model, progeny test, white bolaina, gxe interaction, capirona.

RESUMO

Aniba rosaeodora Ducke, conhecido como "pau-rosa", é uma das espécies arbóreas mais valiosas da Amazônia, famosa pelo seu óleo essencial rico em linalol, utilizado na indústria cosmética. No entanto, sua sobre-exploração tem levado à diminuição de suas populações naturais, afetando sua produção e diversidade genética, colocando a espécie em risco de extinção. A espécie é encontrada principalmente em florestas do Brasil, Colômbia, Equador, Peru e outros países da região amazônica, crescendo em habitats de platôs e riachos, podendo atingir até 30 m de altura. A dispersão das sementes depende de animais como papagaios e tucanos, mas sua regeneração natural está ameaçada pela predação e outros fatores. Este estudo busca entender melhor os padrões de dispersão, densidade e dinâmica da população de *A. rosaeodora* na Amazônia peruana, a fim de propor estratégias para sua conservação e manejo florestal. A dinâmica populacional desempenha um papel fundamental na conservação e domesticação das espécies. A partir de ensaios genéticos de espécies florestais na Amazônia peruana, foram desenvolvidas metodologias para avaliar a variação fenotípica de seus caracteres de interesse comercial. Essas metodologias foram aplicadas em estudos de conservação e domesticação, por meio de testes de estabilidade, adaptabilidade e produtividade de progênies de *Guazuma crinita* Mart, além do controle qualitativo e quantitativo de fenótipos de *Calycophyllum spruceanum* Benth. Esses estudos, realizados na bacia do rio Aguaytía, na Amazônia peruana, podem ser adaptados para aplicação metodológica em *Aniba rosaeodora* Ducke na região, com o objetivo de promover sua conservação e manejo sustentável.

Palavras-chave: floresta amazônica, pau-rosa, densidade populacional, estrutura populacional, dispersão de plântulas, biomassa, modelo alometrico, teste de progênie, bolaina branca, interação g x e, capirona.

LIST OF FIGURES

LIST OF TABLES

SUMMARY

1 INTRODUCTION

Aniba rosaeodora Ducke, or rosewood (Figure 1), is one of the most valuable native tree species in the Amazon biome. Exploited to extract its essential oil containing linalool, a secondary metabolite valued in the cosmetics industry as an excellent perfume fixative (Amusant *et al.*, 2015, 2016; Giongo *et al.*, 2017). Its overexploitation has led to the decline of its natural populations, its production and the genetic diversity of its populations, putting it at risk of extinction in the most exploited areas and leading to its inclusion in the IUCN list of threatened species (May; Barata, 2004; Barstow, 2021).

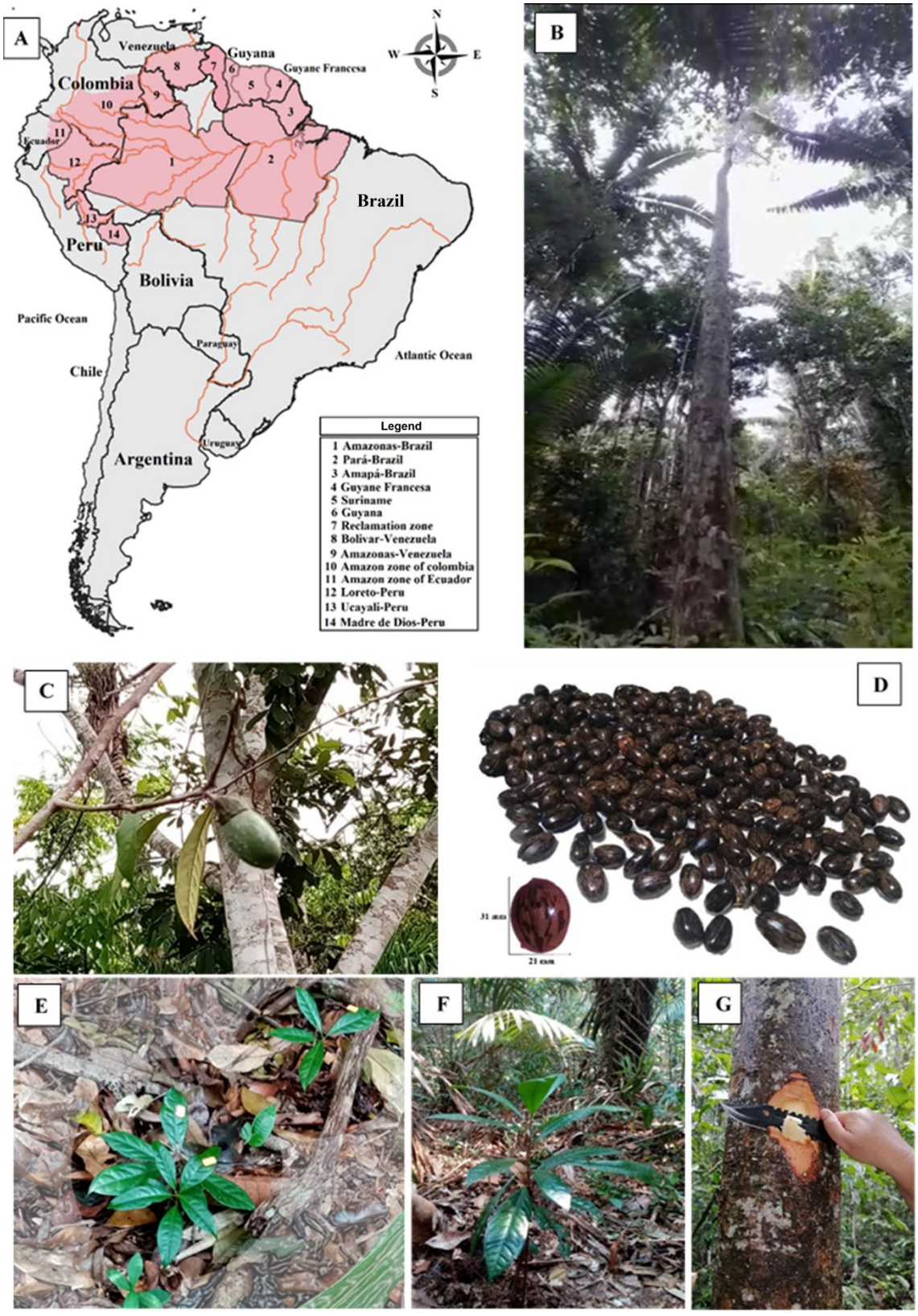
Aniba rosaeodora is a species of the Lauraceae family, with hermaphrodite flowers pollinated by insects, its seeds are dispersed by barochory and zoochory mainly by birds, particularly parrots and toucans (Spironello *et al.*, 2004). Seed production begins when individuals reach about 10 cm in diameter at breast height (DBH) (Spironello *et al.*, 2003). In adulthood, individuals can reach up to 30 m in height and 2 m in diameter at breast height - DBH (Kubitzki; Renner, 1982). In Ucayali, Peru, trees have been reported in natural populations with approximately 25 cm in DBH and a maximum total height of 26 m (Gutiérrez *et al.*, 2023; Revilla-Chávez *et al.*, 2024). The trees have a straight, cylindrical trunk, yellowish or reddish-brown bark that easily separates into large plates, with a narrow, oval crown. It occupies the intermediate or upper stratum of the forest canopy and is found in Brazil, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname and Venezuela (Kubitzki; Renner, 1982). It can be found in both dry and humid forests, with a preferred habitat on plateaus and streams (Kubitzki; Renner, 1982). Population density is generally low, ranging from 2 to 27 trees.ha^{-1} with DBH less than 10 cm in the rainfed forests of northern Manaus, Brazil (Loureiro *et al.*, 1979; Mitja; Lescure, 1996) and 0.12 and 0.16 trees.ha^{-1} for trees with DBH greater than 20 cm near Manaus (Alencar; Fernandes, 1978). The spatial distribution of adult trees is grouped into groups (five to eight trees), with tree spacing ranging from 50 to 100 m and between groups of 300 to 400 m (Alencar; Fernandes, 1978).

Seed dispersal is a fundamental element of natural regeneration that ensures the sustainability of forest resources over time when it occurs in a random and complex

manner (Rodríguez; Mandujano, 2007; Calama *et al.*, 2017). This phenomenon determines the potential area of recruitment of individuals and establishes the basis for subsequent processes, which are influenced by the genetics of the tree, age, position in the forest canopy, among other factors (Campoe *et al.*, 2013). During dispersal, predation is one of the main causes of mortality in the tree's reproductive cycle, reaching up to 60% of which 50% are by insects (Spironello *et al.*, 2003; Norden, 2014; Muñoz, 2018). This can modify the dynamics of the structural composition of forests, in the distribution and abundance of seedlings, juveniles and adults, which can also be affected depending on the level of intervention of the forests (Rasal *et al.*, 2012).

In this context, the present study seeks to fill the gaps in our understanding of the species in terms of conservation and forest management, identifying the patterns of seedling dispersal, density and dynamics of the population structure of *A. rosaeodora* in a natural forest and compare the results with other studies developed to argue the potential for the conservation of the species in the Peruvian Amazon.

Figure 1 - General appearance of the species *Aniba rosaeodora*: A. Distribution map of the species in South America, B. adult tree, C. fruit with seeds, D. seeds, E. seedlings (brinzals), F. sapling (latizals), and G. stem and bark.



Source: Prepared by author

REFERENCES

ALENCAR, J.C.; FERNANDES, N.P. Desenvolvimento de árvores nativas em ensaios de espécies. I. Pau-rosa (*Aniba duckei* Kostermans). **Acta Amazônica**, Manaus, v.8, n.4, p.523-541, 1978.

AMUSANT, N.; DIGEON, A.; DESCROIX, L.; BRUNEAU, O.; BEZARD, V.; BEAUCHÈNE, J. Planting rosewood for sustainable essential oil production: Influence of surrounding forest and seed provenance on tree growth and essential oil yields. **Bois et Forets des Tropiques**, Paris, v.326, n.57-65, 2015.

AMUSANT, N.; BEAUCHÈNE, J.; DIGEON, A.; CHAIX, G. Essential oil yield in rosewood (*Aniba rosaeodora* Ducke): initial application of rapid prediction by near infrared spectroscopy based on wood spectra. **Journal of Near Infrared Spectroscopy**, United Kingdom, v.24, n.6, p.507-515, 2016.

BARSTOW, M. ***Aniba rosaeodora***. **The IUCN Red List of Threatened Species 2021**. Gland, v.e.T33958A88301381, 2021.

CALAMA, R.; MANSO R.; LUCAS-BORJA M.E.; ESPELTA J.M.; PIQUÉ, M.; BRAVO, F.; DEL PESO, C.; PARDOS, M. Natural regeneration in Iberian pines: A review of dynamic processes and proposals for management. **Forest Systems**, Madrid, v.26, n.2, p.eR02S, 2017.

CAMPOE, O.C.; STAPE, J.L.; NOUVELLON, Y.; LACLAU, J.P.; BAUERLE, W.L.; BINKLEY, D.; GUERRIC, L.M. Stem production, light absorption and light use efficiency between dominant and non-dominant trees of *Eucalyptus grandis* across a productivity gradient in Brazil. **Forest Ecology and Management**, Amsterdam, v.288, p.14-20, 2013.

GIONGO, J.L.; VAUCHER, R.A.; DA SILVA, A.S.; OLIVEIRA, C.B.; MATTOS, C.B.; BALDISSERA, M.D.; SAGRILLO, M.R.; MONTEIRO, S.G.; CUSTÓDIO, D.L.; MATOS, M.S.; SAMPAIO, P.T.; TEIXEIRA, H.F.; KOESTER, L.S.; VEIGA-JUNIOR, V.F. Trypanocidal activity of the compounds present in *Aniba canelilla* oil against *Trypanosoma evansi* and its effects on viability of lymphocytes. **Microbial Pathogenesis**, USA, v.103, p.13-18, 2017.

GUTIERREZ, H.; CASTAÑEDA, R.; FLORES, E.; SOTELO-MÉNDEZ, A.; TARAZONA, G. Estimación de la densidad y estructura de la población de palo rosa en el Perú y sus implicaciones para su explotación comercial. **Folia Amazônica**, Iquitos-Perú, v.32, n.1, p.e32661, 2023.

KUBITZKI, K.; RENNER, S. Lauraceae I (*Aniba* and *Aiouea*). **Flora Neotropica**, New York, v.31, p.1-124, 1982.

LOUREIRO, A.A.; SILVA, M.D.; ALENCAR, J.D.C. **Essências madeireiras da Amazônia. Manaus: CNPq/INPA/SUFRAMA**. Boletim de Pesquisa, v.1, 1979, 243p.

MAY, P.H.; BARATA, L.E. Rosewood exploitation in the Brazilian Amazon: Options for sustainable production. **Economic Botany**, California-USA, v.58, p.257-265, 2004.

MITJA, D.; LESCURE J.P. **Du bois pour du parfum: Le bois de rose doit-il disparaître?** In: Emperaire L. (Eds.). La forêt en jeu: l' extractivisme en Amazonie centrale. Paris, OSTROM-UNESCO, p.93-102, 1996.

MUÑOZ, J. Regeneración Natural: Una revisión de los aspectos ecológicos en el bosque tropical de montaña del sur del Ecuador. **Bosques Latitud Cero**, Loja-Ecuador, v.7, n.2, p.130-142, 2018.

NORDEN, N. Del porque la regeneración natural es tan importante para coexistencia de especies en los bosques tropicales. **Colombia Forestal**, Bogotá, v.17, n.2, p.247-261, 2014.

RASAL, M.; TRONCOS, J.; LIZANO, C.; PARIHUAMÁN, O.; QUEVEDO, D. La vegetación terrestre del bosque montano de Lanchurán (Piura, Perú). **Caldasia**, Bogotá, v.34, n.1, p.1-24, 2012.

REVILLA-CHÁVEZ, J.M.; SÁENZ-RAMÍREZ, L.H.; GONZALES-ALVARADO, A.C.; GARCÍA-SORIA, D.G.; SEBBENN, A.M. Allometric models of biomass and essential oils of *Aniba rosaeodora* Ducke in a tropical middle terrace soil forest of Masisea, Ucayali, Peru. **Trees**, **Forests and People**, Netherlands, v.16, p.100594, 2024.

RODRÍGUEZ, A.V.; MANDUJANO, S. **Efectos de la fragmentación sobre la composición y la estructura de un bosque tropical lluvioso Mexicano**. In: Harvey, C.A., Sáenz, J.C. (Eds) Evaluación y conservación de biodiversidad en paisajes fragmentados de Mesoamérica 1ª ed. Santo Domingo de Heredia, Costa Rica: Instituto de Biodiversidad, INBio. p.179-196, 2007.

SPIRONELLO, W.R.; SAMPAIO, P.T.B.; VIEIRA, G.; BARBOSA, A.P. **Ecologia reprodutiva do Pau-rosa (*Aniba rosaeodora* Ducke**, **Lauraceae) em uma mata de terra firme na Amazônia central**. In: HIGUCHI, N.; SANTOS, J.A.; SAMPAIO, P.T.B.; MARENCO, R.A.; FERRAZ, J.; SALES, P.C.; SAITO, M.; MATSUMOTO, S. (Eds.). Projeto Jacarandá Fase II: Pesquisas Florestais na Amazônia Central, Manaus: Editora INPA, p.69-87, 2003.

SPIRONELLO, W.R.; SAMPAIO, P.; DE T.B.; RONCHI-TELES, B. Produção e predação de frutos em *Aniba rosaeodora* Ducke var. amazônica Ducke (Lauraceae) em sistema de plantio sob floresta de terra firme na Amazônia Central. **Acta Botânica Brasílica**, Brasília, v.18, n.4, p.801-807, 2004.

6.5 CONCLUSIONS

We found genetic variation among *G. crinita* progenies for all traits, but no GxE interaction for the studied traits, indicating that the same group of progenies can be selected for all three sites. Compared to H and B, DBH was the most effective variable to select the best progenies in the assessment of genotypic adaptability, productivity, and stability of 200 *G. crinita* progenies at three years of age. Based on the combined analysis of genotypic adaptability, productivity, and stability, with a selection intensity of 25.9%, and considering the highest DBH values, 50 progenies are indicated as ideal for the development of a genetic improvement program.

REFERENCES

AGUIAR, B.I.; FREITAS, M.L.M.; TAVARES, Y.R.; TAMBARUSSI, E.V.; ZANATTO, B.; GANDARA, F.B.; PALUDETO, J.G.Z.; SILVA, D.Y.B.O.; SILVA, J.R.; MORAES, M.L.T.; LONGUI, E.L.; ZANATTO, A.C.S.; SEBBENN, A.M. Genetic control of silvicultural traits in *Balfourodendron riedelianum* (ENGL.). **Silvae Genetica**, Frankfurt, v.68, p.73-78, 2019.

ARAUJO, E.C.G.; SILVA, T.C.; ROCHA, M.P.; SANQUETTA, C.R. Estoque de carbono na madeira de *Eucalyptus*: relação material genético x espaçamento entre árvores. **Revista em Agronegócio e Meio Ambiente**, Brasil, v.14, n.2, p.e7998, 2021.

ARÓSTEGUI, A. **Estudio tecnológico de maderas del Perú - Características tecnológicas y usos de la madera de 145 especies del país**. Ministerio de Agricultura, Universidad Nacional Agraria - La Molina, 1975, 166p.

BARROS, H.B.; SEDIYAMA, T.; TEXEIRA, R.C.; CRUZ, C.D. Análises paramétricas e não paramétricas para determinação da adaptabilidade e estabilidade de genótipos de soja. **Scientia Agraria**, Paraná, v.9, n.3, p.299309, 2008.

CANUTO, D.S.O.; SILVA, A.M.; FREITAS, M.L.M.; SEBBENN, A.M.; MORAES, M.L.T. Genetic variability in *Myracrodruon urundeuva* (Allemão) Engl. Progeny tests. **Open Journal of Forestry**, Warsaw, v.7, p.1-10, 2017.

CASAS, A.; TORRES-GUEVARA, J.; PARRA, F. **Domesticación en el continente americano**, Universidad Nacional Autónoma de México, 1era. edición. México, 2016, 95p.

CHAVES, S.F.D.; ALVES, R.M.; ALVES, R.S.; SEBBENN, A.M.; RESENDE, M.D.V.; DIAS, L.A.S. *Theobroma grandiflorum* breeding optimization based on repeatability, stability and adaptability information. **Euphytica**, Netherlands, v.217, p.211, 2021.

CORAL, L.L.T.; ČEPKOVÁ, H.; LOJKA, B.; WEBER, J.; FILOMENO, S. Genetic diversity in *Guazuma crinita* from eleven provenances in the Peruvian Amazon revealed by ISSR markers. **Bosque**, Valdivia, v.37, p.63-70, 2016.

CORAL, L.L.T.; HLÁSNÁ, C.P.; WEBER, C.J.; BOHDAN, L. Preliminary evidence for domestication effects on the genetic diversity of *Guazuma crinita* in the Peruvian Amazon. **Forests**, v.11, p.925, 2020.

DAWSON, I.; HARWOOD, C.; JAMNADASS, R.; BENIEST, J. Agroforestry tree domestication: a primer. **The World Agroforestry Centre**, Nairobi, KE, 2012, 148p.

ENCARNACIÓN, F. **Nomenclatura de las especies forestales comunes en el Perú**. S.l. Ed. Rev. Lima, 1983, 149p.

FLORES, B. **Especies Forestales 4: la Bolaina blanca**. Instituto Nacional de Innovación Agraria (INIA). Ed. Rev. Pucallpa, 2000, 65p.

FUNGA, A.; TADESSE, M.; ESHETE, M.; FIKRE, A.; KORBU, L.; GIRMA, N.; BEKELE, D.; MOHAMED, R.; BISHAW, Z.; RAO, G.; SIAMBI, M.; MONYO, E.; GAUR, P.; OJIEWO, C. Genotype by environment interaction on yield stability of desi type chickpea (*Cicer arietinum* L.) at major chickpea producing areas of Ethiopia. **Australian Journal of Crop Science**, Australia, v.11, p.212-219, 2017.

LIMA, M.C.D.; BARRETO-GARCIA, P.A.B.; SANQUETTA, C.R.; NOVAES, A.B.; MELO, L.C. Biomass and carbon stock from *Pinus caribaea* var. *hondurensis* under homogenous stands in southwest Bahia, Brasil. **Ciência Rural**, Santa Maria, v.46, n.6, p.957-962, 2016.

MACHADO, J.A.R.; AGUIAR, A.V.; PONTINHA, A.A.S.; SOUZA, B.M.; HALLSWORTH, J.E.; SOUSA, V.A.; FREITAS, M.L.M.; SEBBENN, AM. Enhancing genetic fitness while maintaining genetic variability in *Araucaria angustifolia*. **Scientia Forestalis**, Piracicaba, v.49, p.e3572, 2021.

MARUYAMA, E.; KINOSHITA, I.; ISHII, K.; OHBA, K.; SAITO, A. Germplasm conservation of the tropical forest trees, *Cedrela odorata* L., *Guazuma crinita* Mart., and *Jacaranda mimosaefolia* D. Don., by shoot tip encapsulation in calcium-alginate and storage at 12-25 °C. **Plant Cell Reports**, Germany, v.16, n.6, p.393-396. 1997.

MORAES, M.A.; VALERIO-FILHO, W.V.; RESENDE, M.D.V.; SILVA, A.M.; MANOEL, R.O.; FREITAS, M.L.M.; MORAES, M.L.T.; SEBBENN, A.M. Productive, stability and adaptability in progenies of *Myracrodruon urundeuva* F.F. & M.F. Allemão-Anacardiaceae. **Scientia Forestalis**, Piracicaba, v.40, p.69-76, 2012.

MURILLO, O.; RESENDE, M.D.V.; BADILLA, Y.; GAMBOA, J.P. Genotype by environment interaction and selection in teak (*Tectona grandis* L.) in Costa Rica. **Silvae Genetica**, Frankfurt, v.68, p.116-121, 2019.

MUSTAPHA, M.; BAKARI, H.R. Statistical evaluation of genotype by environment interactions for grain yield in millet (*Penniisetum glaucum* (L.) R. Br.). **The International Journal of Engineering and Science**, Dehradun, v.3, n.9, p.7-16, 2014.

NAMKOONG, G.; SNYDER, E.B.; STONECYPHER, R. Heritability and gain concepts for evaluating breeding systems such as seedling orchards. **Silvae Genetica**, Frankfurt, v.15, p.76-84, 1966.

PAGLIARINI, M.K.; KONRAD, E.C.G.; SILVA, F.C.; SAMPAIO, M.; MOREIRA, J.P.; SATO, A.S.; MACHADO, J.A.S.; FREITAS, M.L.M.; AGUIAR, A.V.; MORAES, M.L.T.; SEBBENN, A.M. Variação genética em caracteres de crescimento em *Dipteryx alata* Vog. **Scientia Forestalis**, Piracicaba, v.44, p.925-935, 2016.

PUPIN, S.; SILVA, P.H.M.; PIOTTO, F.A.; MIRANDA, A.C.; ZARUMA, D.U.G.; MORAES, M.L.T.; SEBBENN, A.M. Genotype x environment interaction, stability,

and adaptability in progenies of *Eucalyptus urophylla* S.T. BLAKE using the AMMI model. **Silvae Genetica**, Frankfurt, v.67, p.51-56, 2018.

PUTZEL, L.; CRONKLETON, P.; LARSON, A.; PINEDO-VASQUEZ, M.; SALAZAR, O.; SEARS, R. **Producción y comercialización de bolaina (*Guazuma crinita*), una especie de rápido crecimiento - Un llamado a la adopción de un marco de políticas que apoye los medios de vida**. CIFOR. Boletin, Bogor, n.25. 2013, 6p.

RAO, P.S.; REDDY, P.S.; RATHORE, A.; REDDY, B.V.S.; PANWAR, S. Application GGE biplot and AMMI model to evaluate sweet sorghum (*Sorghum bicolor*) hybrids for genotype x environment interaction and seasonal adaptation. **Indian Journal of Agriculture Sciences**, Delhi, v.81, n.5, p.438-444, 2011.

RESENDE, M.D.V. **SELEGEN-REML/BLUP: sistema estatístico e seleção genética computadorizada via modelos lineares mistos**. Embrapa Florestas, Colombo, 2007, 359p.

RESENDE, M.D.V. Software Selegen - REML/BLUP: a useful tool for plant breeding. **Crop Breeding and Applied Biotechnology**, Viçosa, v.16, p.330-339, 2016.

RESENDE, R.T.; SILVA, P.I.T.; SILVA-JUNIOR, O.B.; FREITAS, M.L.M.; SEBBENN, A.M.; SOUSA, V.A.; AGUIAR, A.V.; GRATTAPAGLIA, D. Age trends in genetic parameters for growth performance across country-wide provenances of the iconic conifer tree *Araucaria angustifolia* show prospects for early selection. **Forest Ecology and Management**, Amsterdan, v.501, p.119671, 2021.

REVILLA-CHÁVEZ, J.M.; LÓPEZ-GALÁN, E.E.; GUERRA-ARÉVALO, W.F.; GARCÍA-SORIA, D.G.; ROJAS-MEGO, K.C.; DOMÍNGUEZ-TORREJÓN, G.; ABANTO-RODRÍGUEZ, C. Modelos alómetricos a partir de la biomasa de árboles de *Guazuma crinita* Mart. en Ucayali, Perú. **Scientia Agropecuaria**, Trujillo, v.12, n.4, p.579-587, 2021a.

REVILLA-CHÁVEZ, J.M.; ABANTO-RODRÍGUEZ, C.; GUERRA, W.; GARCÍA, D.; GUERRA, H.; DOMÍNGUEZ, G.; CARMO, I.L.G. Modelos alometricos para estimar el de madera de *Guazuma crinita* en plantaciones forestales. **Scientia Agropecuaria**, Trujillo, v.12, p.25-31, 2021b.

REYNEL, C.; PENNINGTON, R.T.; PENNINGTON, T.D.; FLORES, C.; DAZA, A. **Árboles útiles de la Amazonía Peruana y sus usos: un manual con apuntes de identificación**, **ecología y propagación de las especies**. Lima, Tarea Gráfica Educativa, 2003, 509p.

ROCHON, C.; MARGOLIS, A.; WEBER, C. Genetic variation in growth of *Guazuma crinita* (Mart.) trees at an early age in the Peruvian Amazon. **Forest Ecology and Management**, Amsterdan, v.243, p.291-298, 2007.

SERFOR (Servicio Nacional Forestal y de Fauna Silvestre). **Anuario Forestal y de Fauna Silvestre**. MINAG, Lima, 2019, 124p.

SOTELO, M.; BEAULIEU, J.; HERNÁNDEZ, E.; WEBER, J. Genetic variation and correlations between growth and wood density of *Calycophyllum spruceanum* Benth. At an early age in the Peruvian Amazon. **Silvae Genetica**, Frankfurt, v.55, v.217-228, 2006.

SOUZA, B.M.; FREITAS, M.L.M.; SEBBENN, A.M.; GESAN, S.; ZULIAN, D.F.; ZANSTTO, B.; LONGUI, E.L.; AGUIAR, A.V. Genotype-by-environment interaction in *Corymbia citriodora* (Hook.) K.D. Hill, & L.A.S. Johnson progeny test in Luiz Antonio, Brazil. **Forest Ecology and Management**, Amsterdam, v.460, p.117855, 2020.

TORRES-DINI, D.; NUNES, A.C.P.; AGUIAR, A.V.; NIKICHUK, N.; CENTURION, C.; CABRERA, M.; MORAES, M.L.T.; RESENDE, M.D.V.; SEBBENN, A.M. Clonal selection of *Eucalyptus grandis* x *Eucalyptus globulus* for productivity, adaptability, and stability, using SNP markers. **Silvae Genetica**, Frankfurt, v.65, p.30-38, 2016.

UGARTE-GUERRA, L.; DOMÍNGUEZ, G. Índice de sitio (IS) de *Calycophyllum spruceanum* Benth. En relación con la altura dominante del rodal en ensayos de plantación en la cuenca del Aguaytía, Ucayali, Perú. **Ecología Aplicada**, Lima, v.9, n.2, p.101-111, 2010.

USAID-PERÚ; GRU (Gobierno Regional de Ucayali). **UNODC Vulnerabilidad y Riesgos de la Región Ucayali**. Lima, 1era. Ed. Lima. 2012, 175p.

VENCOVSKY, R.; RAMALHO, M.A.P.; TOLEDO, F.H.R.B. Contribution and perspectives of quantitative genetics to plant breeding in Brasil. **Crop Breeding Applied Biotechnology**, Viçosa, v.12, p.7-14, 2012.

WEBER, C.; SOTELO, C. Variation in tree growth and wood density of *Guazuma crinita* Mart. In the Peruvian Amazon. **New Forest**, Oxford, v.36, n.1, p.29-52, 2008.

WHITE, L.; ADAMS, T.; NEALE, B. **Forest genetics**. Cambridge, UK: CABI publishing, p.53-76, 2007, 682p.

YAN, W.; KANG, M.S. **GGE biplot analysis: A graphical tool for breeders**, **geneticists**, **and agronomists**. Florida-United States, CRC press. ISBN.0849313384, 2002, 286p.